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Food Legume Improvement and Development

Proceedings of a workshop held at The University of Aleppo, Syria, 2-7 May 1978

Geoffrey C. Hawtin and George J. Chancellor, Editors

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and the
International Development Research Centre

Contents

Preface

This volume comprises material presented at the First Regional Food Legume Improvement Workshop that was held at the University of Aleppo, Aleppo, Syria, on 2–7 May 1978. It constitutes a synopsis of the current status of food legume production in the countries of Western Asia and North Africa.

The workshop was sponsored jointly by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the University of Aleppo, and had as its primary aims the bringing together of research workers and other legume specialists from all parts of the region served by ICARDA, and the identification of priorities for research attention. More than 15 countries were represented, together with several international and regional research institutions concerned with food legume development. Different specific problem areas were examined on each of the five days and the workshop was structured so that the participants spent a considerable proportion of their time involved in small working parties designed to encourage stimulating discussion and to provide concrete recommendations for future research and development programs.

The workshop and this resultant text are the first steps toward achieving an increasing awareness of the common problems facing food legume production and improvement in the region. They provide a solid base from which to develop appropriate cooperative strategies planned to minimize the constraints that at present limit the production of leguminous crops that are so important both to human nutrition and to the agricultural systems of West Asia and North Africa. It is hoped that future research and development will acquire new cohesion and greater strength from the firm foundations established by this workshop.

Harry S. Darling
Director-General
ICARDA

Foreword

It is well established that the proteins of food legumes and cereal grains are nutritionally complementary, the essential amino acids that are deficient in the one being provided in the other. Consequently, when eaten together, the protein of both cereal and legumes are used more efficiently than if either is eaten alone.

Legumes have figured prominently in the diets of Mediterranean peoples for as long as we have historical records. Several Romans, including Cicero, Fabius, and Lenticulus, bore leguminous names. (I am indeed proud that my own name in the German language means legume.)

It is unfortunate that until comparatively recently, agricultural and food scientists have devoted less attention to legumes than to the principal cereal crops. If soybeans are excluded, world average yields of the major legumes are of the order of 0.5 metric tonnes per hectare compared with about 2.8, 2.3, and 1.7 metric tonnes per hectare for maize, rice, and wheat, respectively.

Building upon the excellent research of the Arid Lands Agricultural Development Program (ALAD), ICARDA has made remarkable progress in establishing its legume research program and in strengthening the regional legume improvement network. From the content of the many splendid papers presented during First Regional Food Legume Improvement and Development Workshop it is evident that we can confidently anticipate significant progress in legume production, both in terms of higher yields and improved quality.

The organizers, the Director-General, the staff of ICARDA, and all who participated in the workshop, whose proceedings are herein recorded, are to be warmly congratulated on the clearly evident success of this endeavour.

Joseph H. Hulse
Program Director
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Section I

An Introduction to Food Legumes in the Region

Some Aspects of the Agroclimatology of West Asia and North Africa

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The region of West Asia and North Africa, which is ICARDA's primary concern, lies very roughly between latitudes 5°N and 43°N and longitudes 10°W and 70°E. It can be broadly divided into main zones of agricultural production: a temperate plateau area, comprising the highlands of Turkey, Iraq, Iran, and Afghanistan; and a lowland area, bordering the Mediterranean and extending inland in areas adjacent to the plateau.

The whole region is characterized by a typical "Mediterranean"-type climate: winter rainfall alternating with summer drought. However, considerable climatic variability occurs throughout the region as a result of the influence of the major geographical features, which include the Mediterranean, the Black and Caspian seas, the mountains of northwest Africa, and the plateaus.

This general climatic pattern means that dryland agriculture in West Asia and North Africa is primarily devoted to temperate crops. The discussion that follows is thus based upon the assumption that ICARDA's main research concern is to improve the productivity and stability of temperate grain and forage crops under dryland agricultural conditions. Attention is concentrated on two major agroclimatic factors, namely, moisture availability, which is considered the most important constraint to crop distribution and yield throughout the world, and temperature, which is also an important consideration in this respect. Such a focus is not meant to imply that other features of the climate are not important in determining agricultural production and strategies for its improvement. Daylength, for example, varies significantly over such an extensive region, and radiation levels vary both with season and altitude. Thus, considerations of photoperiod sensitivity and radiation-limiting periods in some plateau regions are of great importance in crop improvement. However, the effects of these factors are generally considered to be secondary in importance to moisture availability and temperature and for this reason are omitted from the present discussions.

The broad patterns of temperature and precipitation in the region are highlighted in this paper and aspects of their variability are discussed in relation to crop production. Relations between rainfall and soil moisture availability, and between soil moisture, temperature, and crop water requirements are also considered to illustrate the interactions between these components and pose questions of relevance to the development of research programs.

Temperature

Variations in temperature occur with latitude and longitude, decreasing from south to north and from east to west, and, most importantly, with altitude. There are large and obvious contrasts between plateau and lowland regions in this respect.

Low temperature limitations to cropping occur in the plateau regions of Turkey, Iran, and northeastern Iraq. Air and soil temperatures both fall rapidly in the autumn (Fig. 1) and unless the rains are sufficiently early there may be problems of establishment of winter crops before the soil temperature becomes too low for germination, or of crop survival if establishment is insufficient prior to snow cover. Over much of the plateau this snow cover persists for several months and crop growth is not resumed until its dispersal with the rapid rise in temperature in the spring. In the lowland areas, however, winter temperatures are not severe; daytime air maxima appear sufficient to promote photosynthesis in temperate species (Fig. 1) and, although night temperatures often fall below 0° C, some vegetative growth can thus be expected during the winter. Soil temperatures during the crop-growing season do not appear to be limiting in these areas.

Throughout the region there is a risk of crop damage through late frosts during the flowering period. There are marked differences between the plateau and lowland zones in the time at which this risk occurs, and within each zone topographical variation may contribute to differences in the length of the frost risk period (Table 1).

Maximum temperatures increase rapidly in the spring throughout the region (Fig. 1). Although it is difficult to identify a high temperature level critical to crop growth, mean maxima greater than 30–32 °C are frequently experienced in the lowland areas and can be expected to impose a limit on yield potential by hastening crop maturity. Again, relatively localized variations in the time at which extreme high temperatures are experienced are observed (Table 1).

The degree and duration of low temperatures dictate obvious and well-recognized needs for crop types with differing levels of temperature tolerance (spring vs. winter varieties) in the contrasting lowland and plateau zones. However, less obvious differences (illustrated by data for northern Syria in Table 1) are also apparent and may determine the success or failure of different varieties at specific locations. Although such data require further examination to verify that these differences are real and not just artifacts of the siting of the meteorological stations in relation to their immediate topography, they do indicate apparent differences of 2–3 weeks in the duration of favourable growing conditions in a relatively localized area. This suggests the need for a diversity of crop varieties to permit the fullest utilization of local environments.

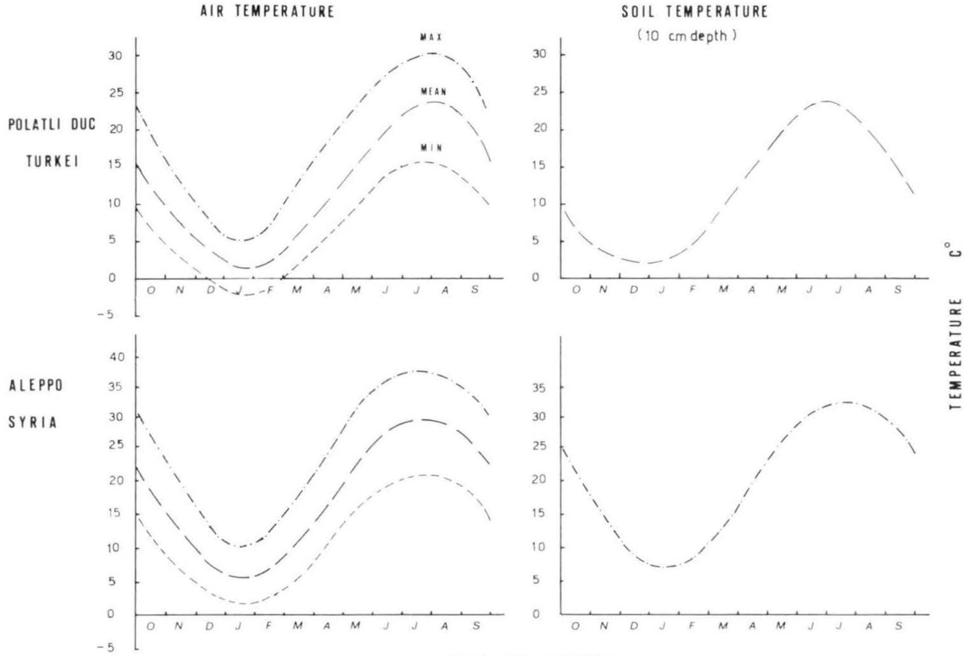

Fig. 1. The seasonal pattern of air and soil temperatures at two locations in West Asia.

TABLE 1. The timing of the occurrence of low and high temperature extremes at four locations in northern Syria.

Name	Location			Timing of last	Timing of first	Timing of first
	Latitude	Longitude	Altitude (m)	frost; T min ⩽ 0 °C[a]	T max ⩾ 33 °C[a]	T max ⩾ 36 °C[a]
Hama	35° 08′	36° 45′	309	3rd wk Mar	3rd wk Apr	2nd wk May
Aleppo	36° 11′	37° 13′	392	1st wk Apr	3rd wk Apr	3rd wk May
Tel Abaid	36° 42′	38° 57′	355	2nd wk Apr	2nd wk Apr	3rd wk May
Kamishly	37°03′	41° 13′	452	1st wk Apr	4th wk Apr	2nd wk May

[a] With a frequency of 1 year in every 13 (based on 13 years of daily temperature data). Source: Monthly Climatological Data, Bureau of Meteorology, Damascus, Syria.

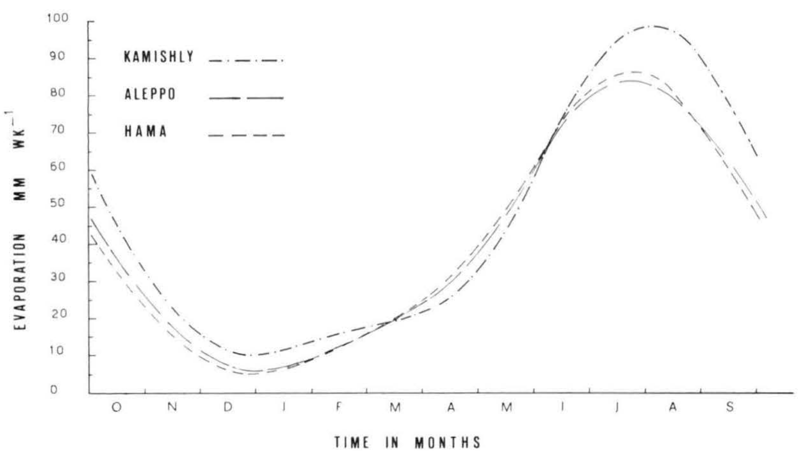

Fig. 2. Seasonal pattern of evaporation at three locations in northern Syria.

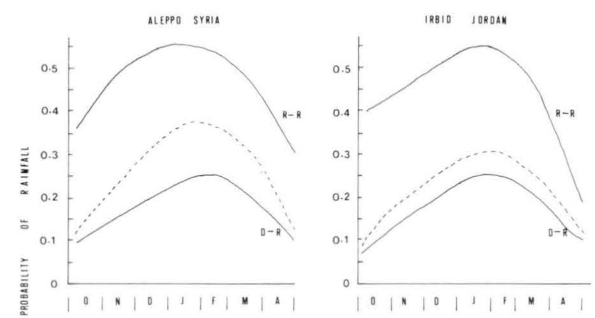

Fig. 3. The probability of daily rainfall at two locations. D-R represents probability of rainfall on day N given that there was no rain on day N−1. R-R represents probability of rainfall on day N given that there was rain on day N−1. Broken line represents independent probability of rainfall on any day.

Evaporation

Because several different techniques are used to measure evaporation within the region, further work is necessary to enable absolute comparisons to be made between locations. In general, however, it can be anticipated that the trends will follow those of temperature fluctuations, showing a decrease in evaporation from south to north and with increasing altitude. Evaporation can furthermore be expected to increase with distance from maritime influences.

The seasonal pattern, common to all the parts of the region, can be illustrated using data from northern Syria (Fig. 2), the major feature being the rapid rise in evaporation rate in the spring, associated with the temperature increases at this time, and, also, in much of the region, with the occurrence of hot dry winds.

Precipitation

Precipitation throughout the region is confined to the period from October to June, but there is considerable variation in its distribution according to location and topographical influences. Reliable rainfall commences earliest in the area adjacent to the mountains of Turkey and in the Azerbaijan region of Iran, and the reliability of early rain decreases with latitude across the region; some areas of Jordan receive their first reliable rainfall only in December. A reversal of this pattern tends to occur with the end of the rains, this being earliest in the south and later in the northern areas, particularly in northeast Iraq and adjacent regions of Iran, where the rainfall peak occurs in spring. A similar pattern appears to hold in a west to east traverse of the northern coastal areas of Africa. The rainfall season is thus considerably shorter in southern and eastern areas of the region, and may be confined to 3 or 4 months only in parts of Jordan. Although isolated coastal areas adjacent to mountains in North Africa, Lebanon, Turkey, and Iran may receive in excess of 1000 mm of precipitation per year, the annual total over the bulk of the region is below 800 mm and in much of the cropping area under consideration varies between 200 and 500 mm. Most precipitation in the plateau areas occurs as snow.

Furthermore, across the whole region and particularly as the annual total decreases, the rainfall is highly variable, the coefficient of variation on monthly data being as high as 50% in inland areas of Jordan, Iraq, Syria, and much of North Africa. In terms of agriculture it is thus important to consider the probability of rainfall and its distribution throughout the season. This has been examined for two locations, Aleppo (Syria) with an annual average rainfall of 470 mm, and Irbid (Jordan) with an average of about 320 mm, using rainfall data for periods of 13 and 40 years, respectively (Fig. 3).

For Aleppo the probability of rain "today" given that "yesterday" was dry is low at the beginning and end of the season (0.1) and rises to 0.25 in midseason, whereas data from Irbid indicate a somewhat lesser chance of rain throughout the season in this more southern area. Given that there was rain "yesterday," the probability of rain "today" is considerably higher at both locations. At Irbid the probability of successive rain days early in the season is slightly greater than at Aleppo. This difference is not evident in midseason, and the probability declines sharply, so that by late April it has dropped well below the Aleppo figure. The higher probability of rain on day n+1, given that day n was wet, illustrates an important feature of the rainfall pattern throughout the region, that is, that rain tends to occur as "rain events" of 2 or more days rather than as isolated falls. Also illustrated by these figures is the tendency for an earlier close to the rain season in the southern areas.

The second stage of such a rainfall analysis involves a consideration of the mean rainfall for each class of rain day (wet following dry, or wet following wet). At Aleppo the mean rainfall is of the order of 6 mm per rain day and does not differ significantly throughout the season or between classes. In contrast to this, rainfall per rain day varies considerably at Irbid, rising to a maximum in midseason and thereafter showing a marked decrease, with a trend toward higher rainfall on one day if the preceding day is wet (Fig. 4).

In addition to the means and probability functions, estimates have also been made of

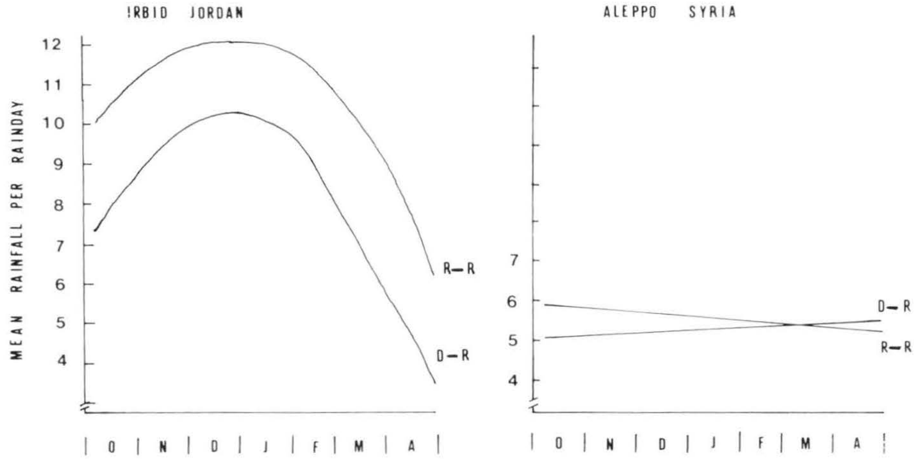

Fig. 4. Mean rainfall per rain-day at two locations.

the distribution of the data about the mean values represented by the fitted lines. In general, these tend to follow a gamma distribution and estimates of the parameters of the gamma functions have been made.

Work is currently under way on the development of techniques for the estimation of the probability and variability of specific events, such as the onset of the rains and hence of expected crop sowing dates, or the occurrence of dry spells of varying duration at critical stages of crop growth throughout the season. Results of these analyses should provide more solid information concerning the risks associated with cropping in the various parts of the region, and in turn may be expected to provide indications of crop types and agronomic practices best suited to the minimization of these risks.

Soil Moisture

Early in the season, when the rainfall is light and sporadic, a proportion will be lost from the soil surface through evaporation. However, moisture is lost readily only from the surface 2–4 cm and once a wetting front has been established below that depth, soil moisture will accumulate with cumulative rainfall. The amount of moisture stored subsequently will depend upon the quantity and intensity of rainfall, the infiltration capacity of the soil, and soil depth. Moisture losses can be expected either through runoff, if the rainfall intensity exceeds the infiltration rate of the soil, or through runoff or deep drainage if the moisture content of the soil approaches field capacity. Where most of the precipitation falls as snow this pattern may be modified by the effects of soil freezing on infiltration.

With a knowledge of this pattern of soil moisture accumulation, information on soil type and depth, and data on the amount and distribution of rainfall, it is possible to predict the total quantity of moisture that will be available for crop growth and its distribution throughout the cropping season. However, a number of specific considerations concerning aspects of the above components vary between locations and will affect the accuracy of predictions. Firstly, there is the question of "effective" rainfall, which is particularly important during early soil moisture build up (i.e., how much rain is required during a rain event to increase the store of soil moisture). The analysis of rainfall presented in this discussion includes all registrations of greater than 0.1 mm and will therefore overestimate the probability of "effective" rainfall. To more accurately predict probabilities of moisture availability from rainfall records, such an analysis must incorporate information to allow "noneffective" rain events to be discounted. Other considerations relate to soil water storage and infiltration capacity. These include the available moisture storage capacity of soils (that moisture stored in the rooting zones of specific crops); the proportion of total rainfall actually stored in the soil as opposed to that which is lost through evaporation and runoff; the effect of varying rainfall intensities and infiltration rates; and the proportion of the moisture accumulated in the rainy season that can be stored, if necessary through a summer drought.

Answers are available to some of these questions in some parts of the region, and in other areas work is under way in an attempt to quantify and expand the present state of knowledge concerning soil–water relations. A coordination of this information with climatic data for the region should provide a basis for achieving a better understanding of the ways in which the most efficient use may be made of the available water resources in dryland farming.

Crop Water Use

The crop water balance depends upon the relative relation between precipitation and water loss from the soil through evaporation and evapotranspiration. An examination of this balance using Penman estimates of monthly evapotranspiration has revealed two critical periods: the first early in the season, determining sowing date; and the second during the flowering and seed-filling stages of crop growth. This situation is general throughout the region, even in the northern areas that have a much greater spring rainfall but also experience lower temperatures and hence a longer duration of cropping.

The general pattern of water use through the annual crop cycle is illustrated in Fig. 5. Early in the season water use is low, although some is usually lost as a result of soil disturbance at sowing. As the leaf area expands, the rate of transpiration increases to a potential maximum, which normally occurs at or about flowering. Where water is not limiting, this maximum rate will be maintained for a period of about 2–3 weeks (both rate and duration being species dependent), after which, with increasing crop maturity and the progressive senescence of leaves, the rate decreases rapidly. Any stress during the vegetative or early reproductive stages of growth can be expected to modify the maximum rate attained, but the general pattern would still remain similar. Estimates from various studies in the region indicate that there will normally be adequate moisture available during the early stages of crop growth and thus that crops will develop high leaf areas and a consequently high evapotranspiration potential. However, the annual termination of rainfall and increase in evaporation tends to coincide with the time at which this high potential is reached and thus the time of greatest crop water demand. Although there is always some reserve of soil moisture available at this time, it is rarely adequate to meet the crop needs, and thus considerable stress may occur. Any strategy for improving the efficiency of water use must consider how best to fit the pattern of crop water demand into the pattern of moisture availability to increase the likelihood of moisture availability at critical periods. Such a consideration requires data on the total amount of water needed for

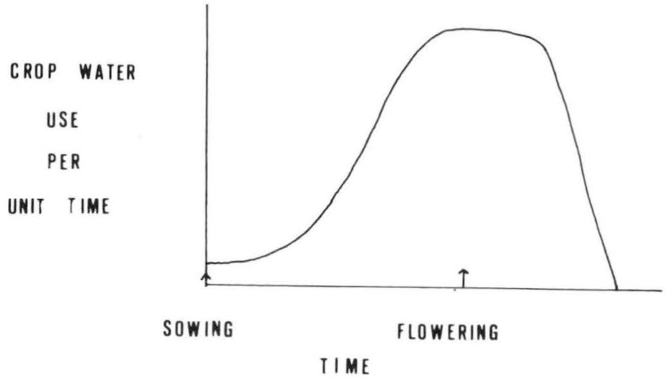

Fig. 5. Typical pattern of water use by annual crops during a growing season.

an "economic" yield and the quantity required at the key times in the crop growth cycle (e.g., at sowing and at flowering and seed fill). A quantification of soil moisture accumulation, storage, and availability and of water use throughout the season for different crops and locations is thus essential to a better understanding of the potential and the limitations of the dryland water resources in the region.

This information should enable the development of agronomic practices designed to modify moisture use patterns. Obvious factors influencing water use and requirements, and which are subject to manipulation, include: weed control to minimize unproductive water use; selection of varieties with maturities that best fit into the pattern of moisture availability (within the constraints imposed by the probability of late frost); timing of sowing; modification of seeding rates to give more optimum plant populations (current rates for cereals in the Aleppo province appear to be unduly high); the interaction of sowing date and rate; and plant nutrition (especially nitrogen status). In the short term the use of a combination of suitably modified practices should lead to a more efficient use of the available moisture and to improved yield stability, if not actual increases.

In the longer term a logical approach to crop improvement would seem to first require an understanding of the crop growth environment interactions as they affect water use. This would enable the development, through breeding programs, of varieties able to make the best use of the available resources to be put on a more solid base.

The improvements possible may be envisaged as being achieved in one of two ways: by drought avoidance or through drought tolerance. Drought avoidance involves the modification of crop growth patterns so that the critical periods of crop water demand coincide more nearly with times of higher rainfall probabilities. The extent to which this is possible is governed largely by the frost tolerance of the crop, the frost risk posed by the environment, and the degree of frost damage that is acceptable. Obviously a requirement for zero frost risk would call for varieties with a longer growing season and consequently higher water requirements than if a small risk of frost were acceptable.

Drought tolerance, on the other hand, refers to the possession by plants of physiological or morphological characters that enable either the production of a greater quantity of dry matter per unit of water used or the fuller utilization of the available water resources. At present the application of developments based upon this concept is hampered by the lack of a more detailed knowledge of the adaptive mechanisms of plants and their effects on yield potential under field conditions. The presence and the relative benefits of the physiological responses known to influence water use efficiency; the role of root systems in drought tolerance; and the relations between shoot and root growth and yield potential are some of the aspects requiring urgent consideration in studies of these adaptive mechanisms. In recent years, however, significant developments have been made in the study of the relations between soil and plant water status, environmental conditions, and plant shoot and root responses, and in the prediction of their effects on crop yield potential. Such advances are contributing considerably to current development efforts, which are mainly focused on the screening of crop varieties originating in the region and in other drought-prone areas (and those that are expected to have evolved mechanisms for adaptation to moisture stress) and should in the future be able to provide a basis for the planned synthesis of plant types designed to optimize their use of the available soil moisture.

Conclusions

There is a considerable wealth of data available relating to climatic conditions throughout the region. These data have been studied on a broad scale in assessments of the region and in more detail for a particular area by various authors, and techniques for further appraisal in relation to periods of critical importance in determining crop yield appear to be available. Further information is undoubtedly available on soil moisture storage in the region, and a collation of this through cooperating national programs would considerably strengthen assessments of the potential provided by the physical environment. Data on plant water use appear to be less available, but are essential in considerations of the water balance of the various crops. Crop water balance, as affected by rainfall distribution (together with other climatic factors), soil moisture storage, and atmospheric moisture demand, must be considered as the key to crop productivity in the "dry areas." It is thus essential that a consideration and understanding of the interaction between the components of agriculture and those of the climate should proceed alongside and as part of crop improvement efforts in the region. Without such an approach, the degree of real improvement in the agriculture of West Asia and North Africa will always be severely limited.

Food Legume Production: The Contribution of West Asia and North Africa to the World Situation[1]

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Biological and cultural factors have, over time, caused a very distinct pattern of pulse production and consumption to develop throughout the world. Over 70% of the annual world production is consumed by humans, largely in the form of dry seed. As a result of their high protein content and relative inexpensiveness, legume grains have traditionally made up a large part of the diets of the rural poor in developing countries. This situation has earned pulse crops the title "poor man's meat," which perhaps effectively underlines their vital importance to the populations of many of the countries of West Asia and North Africa.

Between 1960 and 1975 there appears to have been a stagnation in world pulse production at the level of about 43 million metric tonnes per year. This has been largely attributed to a shift in consumer demand to other staple foods, such as wheat and rice, in many developing countries, a move encouraged by the rapid strides made in cereal improvement over the past decade, and the consequently increased economy of cereal production in the developing world. In the past 2 years, however, there has been a considerable upturn in pulse production throughout the world; annual production now stands at around 48 million tonnes, and reflects a renewed interest in these important crops.

Against this general background this paper sets out to review the production situation of the major grain legume crops in West Asia and North Africa, identify the changes that have taken place over time, and analyze the changing relative contribution of the region to world pulse production.

For the purposes of this study the region of West Asia and North Africa is taken as including the 17 countries of direct concern to ICARDA, namely Morocco, Algeria, Tunisia, Libya, Egypt, Sudan, Saudi Arabia, Yemen A.R., Jordan, Lebanon, Cyprus, Syria, Iraq, Turkey, Iran, Afghanistan, and Pakistan. Comparisons between the production situations in these countries and between the region as against the world as a whole, are made for the five major food legume crops (chick-pea, lentil, dry broad bean, dry bean, and dry pea) over the periods 1966–70 (average) and 1971–75 (average).

The Production Situation

The proportion of the world grain legume production generated by the region has increased slightly from 6.3% in 1966–70 to 6.8% in 1971–75. This increase has been composed of similarly small increases in each of the five major legume crops over the period (Table 1).

Chick-pea

Although the average production of chick-peas in the world has decreased by 1.4% over this period, the level of production from the region has increased by approximately

[1] All figures used in this paper are derived from FAO statistics and in some cases involve FAO estimates, which may be subject to error

Table 1. Average pulse production situation (in 1000 metric tonnes) (1966–70 and 1971–75).

	1966–70					1971–75				
	World		Region			World		Region		
Crop	Production	% of total	Production	% of total	Region as % of world by crop	Production	% of total	Production	% of total	Region as % of world by crop
Dry beans	10907.6	25.7	239.0	8.9	2.2	11637.2	26.1	294.2	9.7	2.5
Dry peas	10246.4	24.1	47.2	1.8	0.5	10936.6	24.5	101.0	3.3	0.9
Chick-peas	6255.4	14.7	855.4	31.9	13.7	6167.2	13.8	910.6	30.1	14.8
Broad beans	4978.8	11.7	556.4	20.7	11.2	5681.0	12.8	699.0	23.1	12.3
Lentils	1017.2	2.4	304.6	11.3	29.9	1108.8	2.5	357.2	11.8	32.2
Others	9024.8	21.3	683.0	25.4	7.5	9024.6	20.3	662.6	21.9	7.3
Total pulses	42430.2	99.9	2685.6	100.0	6.3	44555.4	100.0	3024.6	99.9	6.8

Table 2. Percentage changes in average area, production and yield for the major legume crops of the region (1966–70 and 1971–75).

	Area		Production		Yield	
Crop	World	Region	World	Region	World	Region
Dry beans	-0.3	+12.1	+ 6.7	+ 23.1	+6.0	+ 1.0
Dry peas	+6.3	+73.8	+ 6.7	+113.0	0.0	+10.0
Chick-peas	-3.9	- 2.4	- 1.4	+ 6.5	+2.0	+ 5.0
Broad beans	+6.4	+14.0	+14.1	+ 25.6	+7.0	+44.0
Lentils	+4.0	+ 7.1	+ 9.0	+ 17.3	+4.0	+ 9.0
Total pulses	+2.2	+ 3.4	+ 5.0	+ 12.6	–	–

6.5% (Table 2). The largest chick-pea producers in the region, namely Pakistan, Turkey, Morocco, and Iran, have, between them, contributed about 92% of the regional production in both time periods. However, between 1966–70 and 1971–75, the production in Turkey has been increased considerably, whereas in Morocco and Iran production has declined (Table 3).

Dry Broad Bean

The production of broad beans has increased both within the world as a whole and in the region. However, the increase in production of 26% that has occurred in the region far exceeds the 14.1% increase in world production (Table 2). This has led to an increase in the proportion of the world production generated by the region of approximately 1% over the period (Table 1). Egypt, Morocco, Turkey, and Tunisia are the four largest broad bean producers in the region; Egypt and Morocco together produce over 75% of the total (Table 3). The changes that occurred in the production situation of each country vary considerably between 1966–70 and 1971–75 and are in general not remarkable, with the exception of the dramatic 92% increase in production achieved by Morocco (Table 3).

Lentil

The average production of lentils in West Asia and North Africa increased by 17.3% between 1966–70 and 1971–75, compared to a 9% increase in world production over the same period (Table 2), resulting in a 2.3% increase in the region's contribution to world production (Table 1). Of the region's average annual production, 77% is generated by Turkey, Syria, Iran, and Egypt, and the production has been increased in all of the countries of the region over the period, with the exception of Iran and Iraq, where slight decreases are evident (Table 3).

Dry Bean

Despite production increases of 23.1% in the region as opposed to only 6.7% in the world as a whole (Table 2), the region's share of world production, because it is very small, has only increased from 2.2 to 2.5% between 1966–70 and 1971–75 (Table 1). Turkey and Pakistan are the major dry bean producers in the region, and together with Iran, which has experienced a tripling in production over the period, produce about 84% of the regional total (Table 3).

Dry Pea

The production of dry peas in the region has increased dramatically by 113% in the period under consideration, whereas world production has only experienced a 6.7% increase (Table 2). As is the case with dry beans, however, because of the small amounts of peas produced in the region as compared to world production, this increase still only means that the region produces 0.9% of the world total (Table 1). Morocco is without doubt the single most important producer; accounting for about 78% of this production, and showing a twofold production increase over the period (Table 3).

The Components of Production

Having highlighted the changes in the production of the major pulses that have taken place in the region between 1966–70 and 1971–75, one should now consider the corresponding changes that have occurred in the components of production, namely area and yield, to identify the prime causes for the production changes that have been observed.

In the period 1966–70 the average area of pulse crops grown in the region was 5.5% of the world total. The following years, up to 1971–75, have only shown a slight increase in this figure (to 5.6%). The same slight increases in the proportion of the world pulse-growing area located in the region are evident if one analyzes the individual crops separately (Table 4).

TABLE 3. Average production (in 1000 metric tonnes) of food legumes (1966–70 and 1971–75).

	Total pulses		Dry beans		Chick-peas		Dry peas		Broad beans		Lentils		Others	
Country	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75
Pakistan	738	757	48	54	539	543	–	–	–	–	24	26	127	134
Turkey	589	644	139	153	102	174	5	4	43	48	100	106	201	159
Egypt	381	396	8	14	6	7	2	4	286	272	34	51	44	48
Morocco	306	472	4	5	93	62	37	79	139	268	14	23	20	35
Iran	177	177	12	42	49	43	–	9	–	–	40	35	77	48
Syria	153	168	4	5	36	39	–	1	11	11	62	82	39	30
Sudan	61	71	7	7	2	2	–	–	12	15	–	–	41	47
Tunisia	51	68	–	–	11	16	–	–	25	38	1	1	14	13
Afghanistan	49	54	–	–	–	–	–	–	–	–	–	–	49	54
Iraq	47	41	11	9	4	5	–	–	19	17	6	5	8	4
Yemen A.R.	42	66	–	–	–	–	–	–	–	–	–	–	42	66
Algeria	38	53	2	3	12	16	2	3	15	22	7	8	1	1
Jordan	24	26	–	–	2	3	–	–	3	1	15	18	5	5
Cyprus	14	11	3	1	–	–	–	–	2	3	–	–	9	8
Lebanon	11	13	2	1	2	2	–	–	1	1	2	2	3	7
Saudi Arabia	3	4	–	–	–	–	–	–	–	–	–	–	3	4
Libya	2	5	–	–	–	–	–	–	1	4	–	–	–	–
Region total	2686	3026	249	294	858	912	46	100	557	700	305	357	683	663
%	100	100	9	10	32	30	9	3	21	23	11	12	25	22

TABLE 4. Average areas of legume production (in 1000 hectares) (1966–70 and 1971–75).

	1966–70					1971–75				
	World		Region			World		Region		
Crop	Area	% of total	Area	% of total	Region as % of world by crop	Area	% of total	Area	% of total	Region as % of world by crop
Dry beans	23358.8	35.7	268.8	7.5	1.15	23294.6	34.8	301.2	8.1	1.3
Chick-peas	10381.4	15.9	1494.6	41.5	14.39	9980.2	14.9	1458.2	39.3	14.6
Dry peas	9206.6	14.1	68.0	1.9	0.73	9782.8	14.6	118.2	3.2	1.2
Broad beans	4734.2	7.2	441.6	12.3	9.32	5036.8	7.5	507.6	13.7	10.1
Lentils	1693.2	2.6	436.0	12.1	25.75	1761.0	2.6	467.0	12.6	26.5
Others	16037.4	24.5	885.2	24.6	5.51	17021.6	25.5	862.2	23.2	5.1
Total	65411.6	100.0	3594.2	99.9	5.5	66877.0	99.9	3714.8	100.1	5.6

Consideration of the yield situation, however, shows that, with the exception of dry beans, the percentage increases over the period were greater, in some cases considerably so, in the region than in the world as a whole (Table 2).

Chick-pea

The average area devoted to chick-pea production declined in both the region and the world over the period, the decline in the regional area being in general somewhat less than in the world situation. The increase in the overall production of chick-peas in the region can thus be seen to emanate principally from an increase in average yield, which was more than double the world increase of 2% (Table 3).

The largest chick-pea producing countries in the region (Pakistan, Turkey, Morocco, and Iran) claim this position largely because of the very large areas grown (Table 5); only one of these, namely Turkey, also figures amongst the four highest yielders. Egypt and Turkey, as the two highest yielding countries, produced yields well above those of the other producing countries in both time periods, although while yields in Egypt rose considerably, those in Turkey dropped slightly. Despite being well below these levels, average yields of chick-peas in Iran have shown a fairly dramatic increase (64%) over the period, whereas in Morocco yields have decreased by about 17% (Table 6).

Dry Broad Beans

The increased regional production of broad beans can be seen to result from a 14.9% increase in the production area combined with a 44% increase in average yields. This is in contrast to the world situation where area increases of 6.4% and yield increases of 7% made approximately equal contributions to production increases (Table 2). Morocco, Egypt, and Tunisia have the largest areas devoted to broad bean production, between them possessing about 80% of the regional acreage (Table 5). However, of these, only Egypt combines a large area with high yields, which incidentally are more than twice as much as the other major producers (Table 6). During the period 1966–70 to 1971–75, the greatest broad bean yield increases were recorded in Libya (a very dramatic 280%) and in Syria (38%), while yields in Cyprus dropped by about 17% (Table 6).

Lentils

Both the area and average yields of lentils increased in the region and in the world as a whole over the time period. Increases of 4% in both area and yield made up the world production increase, whilst the increased regional production was composed of a 7.1% increase in area together with a 9% increase in average yield (Table 2).

Turkey, Syria, and Pakistan have the largest lentil-producing areas in the region, but only Turkey and possibly also Syria can be said to achieve reasonable relative yields (Tables 5 and 6). Egypt's position as one of the four top lentil producers in the region stems almost entirely from the high average yields that it achieves. These were nearly twice as great as Turkey in 1971–75 and have increased by 26% since 1966–70. The greatest overall yield increase occurring during this period, however, was of the order of 58% in Tunisia (Table 6).

Dry Beans

Despite only a marginal increase in the average yield of dry beans in the region (1%), as compared to an increase of 6% in the world situation, the production of this crop in the region has increased considerably more than in the world as a whole as a result of a 12.1% increase in the regional production area coupled with a simultaneous decrease of 0.3% in the world area (Table 2).

Pakistan and Turkey have by far the largest areas devoted to dry bean production, but much of the increase in area, and hence production, can be attributed to the fourfold increase that has taken place in Iran between 1966–70 and 1971–75 (Table 4). In terms of yield only, Turkey rates within the top four countries in the region; Egypt again shows yields second to none and a yield increase of 24% over the period, second only to the 40%

TABLE 5. Average area (in 1000 hectares) of food legumes in the region (1966–70 and 1971–75).

	Total pulses		Dry beans		Chick-peas		Dry peas		Broad beans		Lentils		Others	
Country	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75	66–70	71–75
Pakistan	1536	1489	107	111	1066	1000	–	–	–	–	71	75	292	303
Turkey	546	585	109	102	90	158	4	3	33	32	102	113	208	177
Morocco	402	521	8	9	128	98	57	100	153	231	25	39	31	45
Iran	266	221	11	41	100	69	–	6	–	–	61	47	94	58
Syria	206	216	3	4	42	55	–	1	10	8	97	108	54	40
Egypt	202	184	5	7	4	4	2	2	141	114	24	29	27	29
Tunisia	103	118	–	–	25	27	–	–	46	55	3	3	30	32
Algeria	78	96	4	5	27	30	5	6	24	32	17	20	1	3
Iraq	55	52	14	15	5	8	–	–	18	18	10	8	8	4
Sudan	55	64	5	6	2	2	–	–	8	11	–	–	39	45
Yemen A.R.	42	61	–	–	–	–	–	–	–	–	–	–	42	61
Jordan	36	34	–	–	3	5	–	–	3	–	22	22	9	7
Afghanistan	31	33	–	–	–	–	–	–	–	–	–	–	31	33
Lebanon	15	16	1	1	3	3	–	–	1	1	3	2	6	9
Cyprus	15	16	1	1	–	–	–	–	2	3	–	–	11	13
Libya	6	5	–	–	1	1	–	–	4	3	–	–	1	1
Saudi Arabia	2	3	–	–	–	–	–	–	–	–	–	–	2	3
Region total	3596	3714	268	302	1496	1460	68	118	443	508	435	466	886	863
%	100	100	8	8	42	39	10	3	12	14	12	13	25	23

TABLE 6. Average yields (in 1000 metric tonnes) of dry food legume crops (1966–70 and 1971–75).

	Chick-pea			Broad beans			Lentils			Dry beans			Dry peas		
Country	66–70	71–75	% change	66–70	71–75	% change	66–70	71–75	% change	66–70	71–75	% change	66–70	71–75	% change
Morocco	734	606	−17	933	1167	+ 25	548	598	+ 9	526	579	+10	634	781	+23
Algeria	459	519	+13	617	686	+ 11	386	388	0	420	590	+40	466	422	− 9
Tunisia	417	568	+36	573	683	+ 19	256	407	+58	–	–	–	–	–	–
Libya	400	535	+33	287	1091	+280	–	–	–	–	–	–	1450	2250	+55
Egypt	1625	1853	+14	2025	2381	+ 17	1428	1773	+24	1723	2147	+24	1329	1644	+23
Sudan	885	818	−18	1459	1429	− 2	–	–	–	1225	1060	−13	–	–	–
Jordan	506	525	+ 3	850	609	− 28	656	802	+22	–	–	–	–	–	–
Iraq	691	640	−17	1049	973	− 7	646	665	+ 2	756	646	−14	–	–	–
Syria	814	724	−11	1080	1497	+ 38	653	761	+16	1221	1364	+11	880	955	+ 8
Lebanon	705	705	0	1121	1075	− 4	586	694	+18	1353	1313	− 2	1342	1105	−17
Cyprus	–	–	–	1063	873	− 17	–	–	–	1982	1453	−26	–	–	–
Turkey	1134	1115	− 2	1278	1493	+ 16	984	933	− 5	1279	1508	+17	1135	1405	+23
Iran	485	799	+64	–	–	–	660	737	+11	1110	1084	− 2	–	–	–
Pakistan	508	542	+ 6	–	–	–	340	351	+ 3	447	482	+ 7	–	–	–
Region	748	785	+ 5	1028	1483	+ 44	699	765	+ 9	1095	1112	+ 1	1034	1143	+10
World	603	618	+ 2	1052	1128	+ 7	601	629	+ 4	467	499	+ 6	1114	1118	0

increase achieved in Algeria (Table 6). In absolute terms the average regional yield of dry beans is still more than double that of the world although the marginal increase in yield over the period was greater in the case of the world as a whole (Table 6).

Dry Peas

The dramatic production increases that occurred in the region between 1966–70 and 1971–75 can be largely attributed to the 73.8% increase in production area that took place over this period, together with the 10% average yield increase. In contrast to this, the world average yield remained static and the cultivated area only expanded by 6.3% over the period (Table 3).

Of the regional production area, 84% is in Morocco (Table 4), but although yields in this country increased by about 23% between 1966–70 and 1971–75, they are still less than half those achieved in Egypt and Libya, whose yields have also risen by 23 and 55% respectively (Table 6).

Conclusion

From this initial study it can be seen that there is a great variation in the production of grain legume crops throughout the region. Considerable changes can be seen at the individual country level that together have resulted in the region as a whole making an increased contribution to the world production of all five of the crops over the period studied. Despite these fairly appreciable changes, there has been relatively little change in the importance of the individual producers in the region.

In general, the grain legume-producing countries in West Asia and North Africa can be divided into two groups: those growing relatively large areas but achieving relatively low yields; and those in which average yields are relatively high but the area devoted to production is small. There appear to be only a very few countries that combine high yields with a large production area in any one of the crops, and none that achieves this for more than one crop. This indicates the considerable potential for production increases existing within the region, both through marginal yield increases in the large producing areas and through marginal increases in area in the regions already achieving high yields.

However, a large number of different physical, biological, economic, and social factors contribute to the production situation and its propensity to change in each individual country. Therefore, before any concrete conclusions on the likelihood of realizing this potential can be made, further detailed studies of the complete production situation and the factors affecting it in each country are an essential prerequisite.

Food Legumes in the Farming System: A Case Study from Northern Syria

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Food legumes are a very significant component of rain-fed cropping systems in northern Syria, occupying up to 25% of the cropped land area. They are commonly grown in rotation with cereals and summer crops and are an important source of food and income for many of the poorer farmers of the area.

In developing a research program with the main objective of improving the productivity and stability of legume crops, it is essential that an approach involving the consideration of the wide range of variables that affect farmers' capacities to influence production and income be adopted in preference to a fragmented approach considering only the legume crops themselves. Through studies of the whole sphere of farm and household activities, an understanding of the range of choices open to farmers and the formation of farming strategies as related to the development of the family may be achieved. The family, however, should not be the only unit of analysis; comparisons must be made between family groups, between agroecological zones, and between major production areas to fully understand the linkages between local and national structures and the farmers' extent of control over resources. Decision-making and problem definition at the village level has appreciable consequences for policymaking at the governmental level. For this reason, an understanding of the relations between production in different areas, which can be achieved through a thorough comprehension of the distribution of resources and income and the utilization of labour, should be considered to be an important part of such an approach.

This type of research approach also finds considerable application in the development of alternative management systems, in rotations, and in the conservation of land resources.

This paper considers the circumstances of two farming families who represent very different groups of producers, in an attempt to illustrate the necessity for this approach to the solution of the problems of farmers in the developing world.

Background

The study outlined in this paper is a small part of the studies currently under way on the farming systems of the Aleppo Province of Syria. These studies are designed to avoid the past mistakes of concentrating exclusively on the development and transfer of high input technologies. Such emphases have often resulted in the provision of benefits to the minority at the expense of the majority of farmers and have led to an increasing dependence of many agricultural systems upon external aid and support. Farming systems research at ICARDA is based upon an awareness that agricultural development involves people and their needs and that an understanding of these interrelations is essential to the evolution of agricultural alternatives that are operable in the real world. In this context it is considered important to take into account the variation in resource availability between and within agroclimatic zones and, in addition, the large variations in command over resources existing between the minority of rich farmers and the majority group of poor farming families.

The initial studies of this program concern investigations into the social, physical, and biological structure of existing farming systems and detailed analyses of their production processes. This work is based primarily upon surveys of a series of villages located in different ecological zones and exhibiting different forms of agricultural organization.

Village Resources and their Use

The village used for this case study is situated in a high rainfall zone (average annual precipitation is 500 mm) in the north of the province, 70 km from Aleppo and 10 km from Afrin, the district centre. It has a population of 300 people, and all of the 45 permanently resident families own land. Six families, whose members are absent for most of the year, own only trees. The average family size is just over 7 persons, with a range of 1–25.

The total land area around the village is 1070 ha, of which 965 ha are cultivated and 105 ha rangeland. Olive trees occupy about 260 ha. During the land reforms between 1958 and 1963, 310 ha were redistributed to 37 families, and the average holding size is now 10.2 ha (with a range of 2–45 ha); 26 families possess holdings of less than 8 ha. The holdings are usually split between the three main soil types: a deep red cracking clay on the lower slopes, a brown–grey stony loam of about 60 cm in depth on the middle slopes, and a shallow black heavy clay loam on the upper slopes. The average number of plots per holding is four.

A two-course rotation involving wheat, barley, lentils, chick-peas and broad beans as winter and spring crops, and cotton, melons, and sesame as summer crops (following a winter fallow) is commonly practiced on the arable land. However, in recent years the area devoted to lentil production has declined as a consequence of a reduction in the guaranteed price and this has led to a simplification of the rotations. Vines and summer crops are commonly interplanted between young olive trees before they come to bear, but once they become productive the ground beneath them is kept clean.

Thirty-two families own livestock, amounting to 227 sheep and 210 goats; and 12 of these 32 families also own draft animals. There are five tractor owners in the village and they carry out most of the cultivation operations. One combine harvester is present.

The village has a cooperative membership of 40, most of whom receive short-term loans for fertilizer and medium-terms loans for the purchase and establishment of olive trees from the organization. The cotton crop is marketed through the cooperative, but most of the other crops are sold individually on the black market in preference to using the government channels. A primary school is situated in the village but no electricity, telephone, or piped water is available. A new road is at present being constructed to link with the main local highway and should be completed by the winter of 1978–1979.

This information provides the base for the continuing in-depth study of climate, soils and cropping, farm operations, and household income and expenditure over several seasons. A total of eight farming families, covering the range of land/person ratios of village households, were selected as a sample for the further studies and two of these family situations are discussed in this paper. A summary of each family's resources is given in Table 1, and the ways in which the household requirements are generated and the interrelations within the farming systems operated by each family are illustrated in Fig. 1 and 2.

Discussion of the Individual Family Circumstances

The main point of contrast between the two families studied is that the larger landholding and greater number of productive olive trees owned by family A (8 persons) provides a stable and high income for that group; whereas the smaller land area (about average for the village) and number of trees of family B barely provide sufficient income or food to supply the annual needs of the household of 10 persons (Table 2). Consequently, the head of family B is forced to supplement the household income by working as an agricultural labourer for some periods during the year and the family is dependent on a variety of loans to maintain the household.

The cropping system of family A is dominated by olive production, which, as it provides the bulk of family income (Table 2), receives first priority in care and attention. Cereals are the most important field crop, Mexipak wheat being grown as a cash crop and the local variety "Hamari" as the main food grain, which is stored from one season to the next. Lentils and

TABLE 1. Resources and their use for two households from a village in Northern Aleppo Province, Syria.

Resources	Family A	Family B
Family size	8	10
Ages: Males	**65**, 25, 22, 15, 13, 9	**30**, 12, 10, 6, 2, 6 months
Females	**45**, 18	**30**, 14, 8, 4
Land (ha): Private	33.5	3.0
From land reform	–	6.1
Crops 1977–78 (ha)		
Wheat: Mexipak	4.0	2.0
Hamari	2.0	0
Barley	0.1	0.5
Lentils	0.5	0.6
Chick-peas	6.0	2.2
Broad beans	0	0.05
Olives	8.0 (600 trees)	3.0 (200 trees)
	7.0 (500 not bearing)	1.0 (not bearing)
	7.0 (500 in another village)	
Livestock		
Sheep	3	0
Goats	8	7
Cattle	1	0
Chickens	16	15
Machinery	Tractor, plough, trailer, cultivator	None
House	Stone-built, 3 rooms, kitchen	Mud brick, 1 room, kitchen
Possessions	3 diesel stoves, 2 pres. lamps, 2 butagaz rings & cylinders, cupboard, sideboard, 2 chairs, table sewing machine, 2 radio recorders	1 diesel stove, 1 primus cooking stove.
Loans	Private	From Agricultural Bank

TABLE 2. Expenditure and income for period November 1977 to August 1978 (Syrian pounds).[a]

	Family A		Family B	
	Expenditure	Income	Expenditure	Income
Cropping	4255	1407	2699 (1538)	4166
Livestock	1170	466 (1400)	573	–
Household	16349	–	2805 (497)	–
Food	2453	–	2741 (651)	–
Machinery	4545	350	–	–
Other	–	–	–	780[c]
Total to end August 1978	28772	2223	8818	4946
Estimated total annual expenditure and income	33351	45957[b]	12843	14546[b]

[a] Syrian pound = ca. U.S. $0.25 (August 1978).
[b] Including income from olives estimated as 42334 Syrian pounds for family A, and 9600 Syrian pounds for family B.
[c] From agricultural labouring.

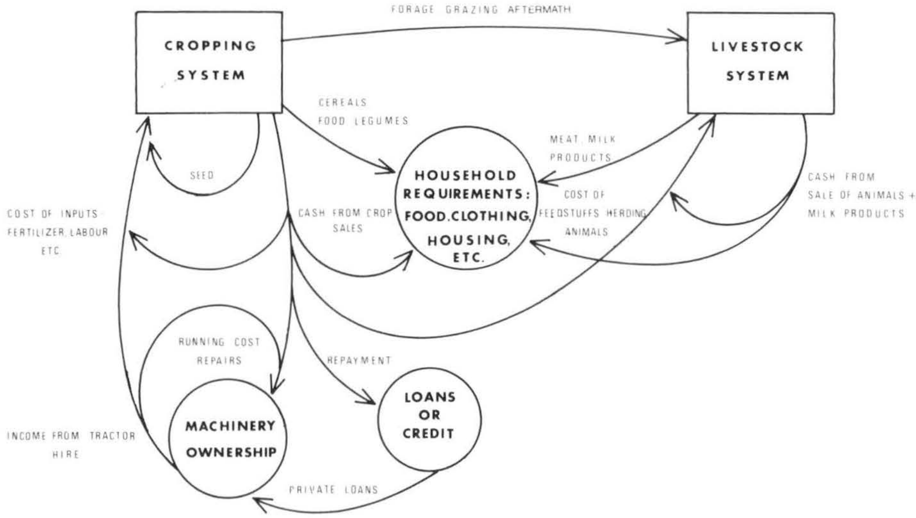

Fig. 1. Ways in which household requirements are generated and the interrelations within farming systems operated by family A.

chick-peas are produced on an area similar to the cereal crops, but are generally regarded as less important by the household and are consequently not as well managed. This may, in part, be due to the reduction in the family female labour force resulting from the marriage of two of their daughters, as tending the legume crop is traditionally regarded as female work. Both legume crops, however, are important sources of food for the household through the year and the surplus over consumption requirements is stored and sold periodically according to seasonal cash needs. Chick-peas are the most important of the two crops, especially as a poor harvest in

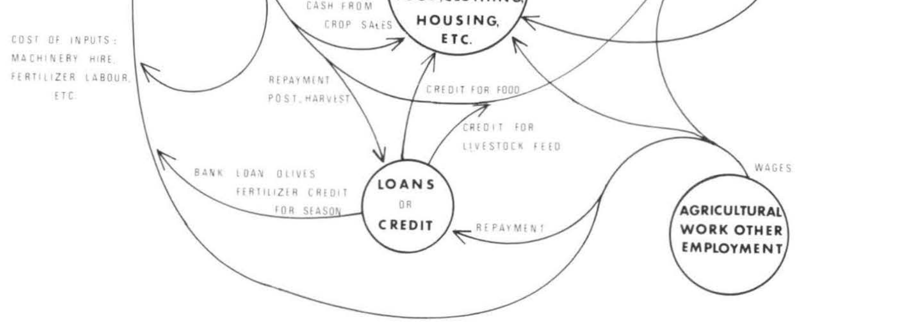

Fig. 2. Ways in which household requirements are generated and the interrelations within farming systems operated by family B.

1976–77 and a drop in market price have caused the family to reduce their lentil area in the current season. A summary of operations, yields, and crop disposal for lentils and chick-peas is given in Table 3.

The machinery owned by family A (Table 1) is used both on the family lands to reduce labour needs and provide transport, and to earn additional income through contracted services to other families. However, repair costs are high and the income from machinery only just covers expenditure.

Livestock have become less important for this family with their reduced animal-managing capacity caused by the departure of two daughters already mentioned. It is appreciated that this reduction in livestock has been followed by a decline in the use of organic manure, a consequent decline in soil organic matter, and an increasing dependence upon inorganic fertilizers.

The family usually pays cash for most goods and receives some short-term credit for machinery repairs (Fig. 1).

Family B, in contrast, has a much greater dependence upon arable crops and, as a result, practice higher standards of general husbandry. There is a much greater interaction between livestock and cropping in this farming system (Fig. 1 and 2). Again, the main field crop is

TABLE 3. Operations, yields, and disposal of grain legumes for two farming families.

Crop	Family A	Family B
Lentils		
Area	0.5 ha	0.6 ha
Ploughing	Mouldboard 3 Sep & 15 Dec	None
Cultivating	15 Dec	1 Jan
Planting	Broadcast by hand 15 Dec 120 kg seed/ha	Broadcast by hand 1 Jan 130 kg seed/ha
Weeding	None	By hand, 1 Apr
Fertilizer	None	50 kg triple super phosphate
Harvest	By hand, 15 May	By hand, 18 May
Yield	250 kg seed + 120 kg straw	260 kg seed + 300 kg straw
Disposal: Sale	None	None
Food	150 – 200 kg	130 kg
Seed	50 – 100 kg	130 kg
Chick-peas		
Area	6.0 ha	2.2 ha
Ploughing	Mouldboard 20 Feb & 2 Mar	Mouldboard 7 Jan & 8 Mar
Cultivating	21 Mar & 23 Mar	–
Planting	Broadcast by hand 22 Mar 120 kg seed/ha	By hand, 8 Mar 136 kg seed/ha
Weeding	None	By hand, 20 May
Fertilizer	None	Organic manure: 2 trailers + 50 kg Knitro (26% N)
Harvest	By hand, 14 Jun	By hand, 15 Jun
Yields	1500 kg grain + 200 kg straw	2500 kg seed + 2 tonnes straw
Disposal: Sale	625 kg (according to cash need)	1875 kg
Food	250 kg	} 625 kg
Seed	625 kg	

wheat, with the variety Mexipak being preferred for its high yield. The family is, however, not self-sufficient in wheat and was buying grain for home consumption from January in the year in question (1978). Legume crops are relatively more important to this family and, although a proportion of the lentil and chick-pea crops are retained for food and seed, the bulk is sold and generates as much income as Mexipak wheat. These crops thus provide an important source of cash at times of need through the season and are consequently well cared for. The lentil crop was grown on land cultivated on the contour and phosphate fertilizer was applied, as was also the case with chick-peas, which received, in addition, organic manure. Both crops are kept weed-free by the children. The 1977–78 chick-pea area was increased in response to an improved price differential with lentils. In addition to lentils and chick-peas, two small plots of broad beans were also grown for family consumption (Tables 1 and 3).

The cash received from crop sales is used for household purchases, the repayment of loans, and the purchase of inputs, including seed. The family uses loans from the Agricultural Bank for olive production and fertilizers and these are repaid at the end of each season. Credit is also received for livestock feed and food and this is usually repaid from the income generated by agricultural labouring (Fig. 2).

Conclusions

The contrasting circumstances of these two families suggest the value of a consideration of the ways in which the source and possession of resources and levels of income structure the possibilities and choices of different families.

There is scope for the improvement of legume production in both cases. However, this is much less obvious for family B in view of their superior crop management and the lower degree of flexibility existing within their household economy for the allocation of additional resources to legume production. Family A, however, with its higher and more secure income, is in a better position to afford changes in input levels, varieties, or management techniques. In this case, the present income adequately covers the family's needs and the adoption of changes will thus depend upon the family's perception and evaluation of the relative advantage of increased legume yields as against the advantages of investing in other alternatives. The recognition that, in these circumstances, objectives other than the maximization of yield and cash income are more highly regarded indicates that more attention would be given to those families represented by the second case for whom increased yields and income are urgent needs.

Such families find it very difficult to adapt their cultivation methods or increase inputs without the additional cost of these measures increasing their level of debt and dependency. Although the eventual improvement in productivity and income would more than justify the increased costs involved, the difficulty of financing the initial steps, especially if they are presented in terms of a package of practices with no sequential ordering of components, still remains a major stumbling block. However, even small improvements would be of great importance to these families, providing that the starting point is within their present capacity. This finding strongly indicates that research is more appropriately directed toward the development of low-cost stepwise recommendations relevant to most farming families who fall into this category, even if less spectacular results are achieved. High-input, high-cost packages, yielding spectacular improvements, would seem to benefit only a minority of farmers (providing of course that they chose to adopt them) for whom the need is less urgent, and would serve to accentuate the present disparities of wealth that exist in the farming community as a whole.

The circumstances of the poorer families are common both within the study village and the region as a whole. It is this group of farming families who make up most of the farming community in many areas to whom the bulk of farming systems research in the region should be directed. Such a commitment has important consequences for the whole organization of research: in the composition of research teams, in the identification of research priorities, and in the conduct and location of research work.

Nutritional Quality and Importance of Food Legumes in the Middle Eastern Diet

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Grain legumes constitute one of the most important sources of food nutrients to people in many countries of the world, particularly in the Middle East. Their main nutritional value lies in the fact that they are very important sources of dietary vegetable proteins. They provide 15–30% of the total protein content of average diets in this part of the world, making them second only to cereals in dietary importance. Grain legumes are also good sources of the vitamins thiamine and niacin and the minerals calcium and iron, but contain little fat, carotene, or ascorbic acid.

The food legumes commonly consumed in the Middle East together with their Arabic names are: broad beans (*Vicia faba*), "ful"; chick-peas (*Cicer arietinum*), "homos"; lentils (*Lens culinaris*), "adas"; fenugreek (*Trigenella foenumgraecum*), "hilbeh"; lupins (*Lipinus* spp.), "turmos"; peas (*Pisum sativum*), "bazella"; and common beans (*Phaseolus vulgaris*), "fasulya nashef". Of these, broad beans, chick-peas, and lentils are the most important and are probably consumed daily in one way or another by a large part of the population of the Middle East. During the harvesting season the green seeds of broad beans, chick-peas, and lupins are commonly consumed as an interim food, the latter only after debittering. Fenugreek is used mainly as a condiment, particularly in the very popular Armenian dish "basterma," and peas and common beans are used in a stew with meat and usually consumed with rice. The most common legume dishes consumed in the area are: broad bean dip, "ful moudamas," which is frequently eaten as a breakfast food; chick-pea dip, "hommos bitehineh," eaten at any time; rice and lentils, "mujaddarah," and common bean stew, frequently served at schools and other institutions; "falafel," often eaten as a sandwich; and lentil soup, which may be eaten at any meal.

Nutritional Composition of Grain Legumes

The importance of legumes as a protein source is clearly illustrated in Table 1. The average protein content varies from 20 to 40%, which is approximately triple that of cereals. However, with the exception of chick-pea and lupin, the fat content of these seeds is rather low. The nutritive value of legumes changes with the development of the seed, the fat content increasing until 21 days after flowering and thereafter remaining stable, and the protein content remaining the same throughout despite the lysine content rising to a maximum after 14 days and the sulphur amino acids after 42 days. This may have a bearing on the fact that chick-pea seeds are frequently consumed green during harvest.

In any evaluation of dietary value, the protein quality of a food should be considered of equal importance to the total protein content. An evaluation of quality on the basis of the chemical score of the most limiting amino acids (in this case the sulphur amino acids) shows chick-pea to contain the best quality protein (score = 61), followed by lupin (55), and lentil (44), with broad bean (34) showing the lowest quality.

Most dry legumes are good sources of thiamine and niacin, but with the exception of green chick-peas, are poor sources of carotene and vitamin C. Legumes also have a high

Table 1. Chemical composition of grain legumes (grams per 100 edible portion).

Legume	Protein	Fat	NFE	Ash	Fiber	Water	Energy (Kcal)
Broad beans, green	5.2	9.4	9.8	0.8	2.0	81.8	72
Broad beans, dry	25.0	1.8	53.7	3.0	5.9	10.6	354
Chick-pea, green	5.9	1.8	17.5	0.9	1.3	72.6	99
Chick-pea, dry	19.2	6.2	56.7	3.0	3.4	11.5	376
Lentils	23.7	1.3	57.4	2.2	3.2	12.2	351
Lupin	40.0	13.0	26.0	3.0	9.0	9.0	420
Fenugreek	29.6	5.2	50.0	3.3	7.2	8.6	365

Table 2. Nutritional composition of some Middle Eastern legume dishes (per 100 g edible portion).

Legume	Water, g	Protein, g	Fat, g	Energy (Kcal)	Ca, mg	Fe, mg	Thiamine, mg	Riboflavin, mg	Niacin, mg	Lysine, mg/gN	Total S-AA, mg/gN	FAO Score 1957
Broad bean dip (ful moudamas)	66.1	9.1	3.1	151	43	2.2	.15	.1	.9	346	129	48
Chick-pea dip (homos bitehineh)	49.5	9.6	19.7	300	57	4.2	.33	.08	1.2	330	195	72
Lentil soup	83	4.7	.8	72	14	1.4	.09	.03	.4	380	130	48
Lentil + rice (mujaddarah)	64.5	6.2	5.6	170	15	1.4	.09	.05	.9	386	163	60
Falafel sandwich	28.6	5.8	12.0	195	40	5.9	.06	.06	.5			

Table 3. Effect of cooking (autoclaving at 121 °C) on antinutritional factors in legume seeds.

	Hemagglutinating activity		Antitrypsin activity		Mortality[a]	
Legume	None	20 min	None	20 min	None	20 min
Broad beans	80	0	0	0	1	0
Chick-peas	0	0	8.4	0.6	0	0
Lentils	640	0	0	0	4	0
Pea	80	0	8.4	0.8	3	0
Common bean	8200	20	9.6	0.8	10	1

[a] Number of rats dead (out of 10) after 4 weeks.

content of iron and other minerals, but the availability of these minerals may not be very high.

Nutritional Evaluation of Legume Dishes

Because grain legumes are consumed in the form of composite dishes, the real dietary value of the food must be considered in terms of the nutritional value of the complete dishes (Table 2) and the frequency with which these dishes are consumed. Furthermore, when a specific food or dish is continuously consumed, specific nutritional implications must be considered. The digestibility, physiological availability of certain nutrients, presence of antinutritional factors, problems of flatulence, and effects of processing all become more important in this case due to an accumulation of effects. For example, where legumes provide the major source of protein in the diet, the nutritional quality of the legume proteins becomes a much more limiting factor. The protein quality of chick-peas is higher than the other legumes, and the protein quality of the most common legume dish "hommos" is correspondingly high (Table 2). Therefore, the frequent consumption of chick-pea dip will be better than any of the other legume foods. To achieve a more balanced diet, legume foods may be supplemented with other foodstuffs. From the protein quality point of view, bread is an ideal complement to legume foods. It is, thus, nutritionally very fortunate that most legume dishes are consumed with bread. The notable deficiencies in legume foods, namely carotene and vitamin C, may be remedied by the inclusion in the diet of other foods rich in these nutrients.

Effects of Processing on Nutritional Quality

Uncooked legume seeds contain antinutritional factors that can be very toxic if consumed in large quantities (Table 3). Consideration of only two factors, namely hemoglutinating and antitrypsin (although other factors may well be responsible for the mortality of animals fed on uncooked beans), illustrates that adequate cooking will render them safe for consumption.

In general, cooking also improves protein quality in legume foods, but it should be noted that prolonged cooking (longer than 5 min at 121 °C) will not improve quality further.

Utilization of Grain Legume Flours as Supplements

Because grain legumes are a good source of dietary protein, it is envisaged that legume flours could be profitably used as supplements to improve the dietary protein quantity and quality of other local foods. Several investigations along these lines have been carried out at the Faculty of Agricultural Sciences with legume flours, protein isolates, and concentrates utilized as supplements to weaning food mixtures, Arabic bread, biscuits, and other foodstuffs. It was generally found from these investigations that legume flours can be used in limited quantities to improve the protein quality of local foods without seriously affecting their taste, acceptability, or other quality factors.

Cooking Quality of Food Legumes

Dry legume seeds normally require a relatively long time to cook. Seeds of broad bean, chick-pea, common bean, and, to a lesser extent lentil, are soaked in water overnight before cooking as a means of reducing the cooking time and, in some instances, small amounts of $NaHCO_3$ may be added to chick-peas and broad beans to reduce this even further. Not all food legumes are eaten cooked, however, and unprocessed dry seeds of many of the legumes are often used directly in the preparation of traditional dishes in the Middle East and neighbouring countries.

The cooking process serves to soften the hard legume seeds by improving the plasticity of the cell walls, thereby facilitating cell expansion and the reduction of cellular adhesion. Some legume seeds are more difficult to cook than others and this is thought to be due to the presence of insoluble pectins in the middle lamella of the cell wall. This may be accentuated by the formation of further insoluble calcium and magnesium pectates in these middle lamellae when the Ca or Mg content of either the seed or the cooking water is high.

It has been reported that cooking quality may be associated with the ratio of monovalent to divalent cations and with the phytin and phosphorus contents of the seed. It seems that a high availability of phosphorus in the soil could contribute to a high phytin content in the seed and consequently to good cooking; and it has been suggested that the action of phytin in this respect is as a Ca absorbent, which thus prevents the formation of calcium pectate. Besides the relative contents of phytin, Ca, Mg, and free pectin in the seed, it has also been reported that the thickness of the palisade layer, and the lignin and alpha-cellulose content of the seed coat, are probably important factors affecting the cooking quality of legume seeds. Cooking quality has further been found to be affected by storage but only when the moisture content of the seed is greater than 10%.

Work at the Faculty of Agricultural Sciences on these aspects has been confined to studies on lentils. A standard procedure for determining cooking quality has been evolved and all experimental results are expressed as a cooking index on a scale of 1–15, where good quality is expressed by low scores. It has been found that quality is significantly influenced by mineral nutrition, with adequate levels of both the major and the trace elements contributing to good cooking. Plants receiving adequate levels of the important elements and a high level of potassium produced the fastest cooking lentil seed, and a combination of high levels of potassium and sodium in the seed was also associated with good cooking quality. No direct relation was found, however, between the content of phytic acid in the seed and cooking quality.

Various growth regulators or the chelating agent EDTA, applied as foliar sprays during early crop development, had no significant effect on the cooking quality.

The results of field experiments to study the effects of seed maturity on cooking quality demonstrate that cooking time decreases markedly with increasing maturity.

It can be seen that food legumes, in a variety of different forms, contribute considerably to the diets of the people of the Middle East, especially in terms of high quality protein. However, the presence of various objectionable endogenous factors, such as antinutritional factors, flatulence, and poor cooking quality, tends to limit their more widespread utilization in human diets. The neutralization and minimization of the effects of these factors should be the prime focus for future research geared to increasing the consumption of these important dietary components.

Section II
The Present Production and Improvement Situation

Food Legumes in Algeria

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Historical Considerations

With the exception of beans, the cultivation of legume crops in Algeria can be traced back over many thousands of years to the dawn of plant domestication in the region of the Near East and North Africa. The species have, since then, evolved through small-scale cultivation in isolated local populations, and even up to the period between the French occupation and World War I, it has proved almost impossible to define the areas of land devoted to the cultivation of individual crops. Figures available from World War I onward indicate considerable fluctuations in dry legume seed production in the country, as can be seen in the following figures:

	Production area (ha)				
Year	Peas	Broad beans	Chick-peas	Lentils	Dry beans
1929	18127	38014	27630	1329	1152
1952	8000	45000	25000	40000	–
1964	5700	22890	18230	8400	2040

As the legume crops have traditionally been produced locally for local consumption, these variations have tended to reflect variations in population stability, especially the availability of manpower and seed. Furthermore, disturbances on a national scale in the 1950s and early 1960s resulted in a sharp drop in production throughout the country in this period.

The Present Production Situation

With the preoccupation of the country in improving the standard of living of its population that has been evident over the last decade, the cultivation of dry legumes has been encouraged. The use of legumes in rotation with cereals to replace the traditional fallow course has been shown to provide considerable cultural, as well as the more obvious economic advantages, through improvements in soil fertility and workability. In addition to this, legumes have proved valuable in intercropping with grapes and other fruit trees. The western parts of the country, with their high rainfall (400–500 mm) and large percentage of fallow land are particularly suitable areas for this type of intensification.

Despite these proven advantages, the structure of production and commerce and the relatively low consideration given to legume crops in the period prior to 1975 resulted in a steady decline in production up until this time (Table 1). To meet its domestic consumption requirements, the country was thus forced to import considerable quantities of legumes. However, after 1975 increasing encouragement was given to domestic production in the form of price incentives, as illustrated below:

Prices paid to producers in dinars/quintal (1968–1977)

	1968	1974	1977
Lentils	88	90	250
Chick-peas	80	80	200
Broad beans	55	60	150
Beans	140	150	270
Peas	55	60	150

This has largely served to offset the great increases in the costs of inputs that occurred during this period but has so far failed to put legume production on a viable economic footing.

The Current Status of Production Practices

Food legumes almost invariably follow a cereal crop in the rotation, and in only very few cases are they planted following a fallow. The presowing land preparation consists of deep ploughing, with either a disc or a mouldboard plough, followed by cultivation with a disc harrow to break the clods, and is essentially identical to the preparation for a cereal crop. Prior to planting and after the first rains of the season the land is again disked to control weeds and further refine the seedbed. All the legume crops are row planted, as this facilitates weed control later in the season, lentils being almost entirely planted using a seed drill, whereas chick-peas, dry peas, and broad beans are, in general, hand seeded into previously opened furrows. Between-row spacing varies from 1–4 m, depending upon the size and type of cultural weeding equipment available, and may be fairly haphazard. Lentils and chick-peas are usually spring sown, lentils between mid-January and mid-February, and chick-peas between mid-February and mid-March, although actual dates vary considerably from the low altitude plains where the season is earlier to the later season high plateau areas. In contrast, broad beans and field peas are grown as winter crops and generally planted between late November and late December.

Natural *Rhizobia* have been found to exist in almost all the soils in which legumes are cultivated and for this reason seed inoculation is not carried out in Algeria. Fertilization is common throughout the pulse cropping areas, and phosphate is normally applied at the rate of 90 kg/ha in the fall. Nitrogen fertilization is not widespread, but 30 kg/ha may be applied post-planting or post-emergence. Algerian soils are believed to be rich in available potash and the use of fertilizers containing this macroelement is thus rare.

The bulk of the legume crops in Algeria are hand harvested: pulled from the ground, gathered in small heaps, left to dry, rearranged into larger piles, and threshed by stationary machines. In many cases, crops may be hauled to the farm yard for threshing, thus increasing yield losses that may be as high as 15–20% as a result of these operations. Recently, attempts at direct combining of lentils and chick-peas have met with some success, but such methods are still limited by the incorrect adjustment of the threshers, which results in a high percentage of damaged seed.

Important Pests and Diseases

Blight, caused by *Ascochyta rabei*, is without doubt the most important disease of chick-peas in Algeria, appearing on average once every 3 years and causing crop losses as high as 80%. *Ascochyta* species have also been identified as infecting broad bean crops but damage is seldom as serious. Both chick-peas and broad beans are commonly infected with

TABLE 1. Area production and yield of dry legumes in Algeria 1969–76.[a]

Year	Lentils			Chick-peas			Broad beans			Peas			Total		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1969	23670	107000	4.5	28660	113310	4.0	23200	140070	6.0	10880	41900	3.8	86420	402280	4.6
1970	20830	47120	2.7	21850	63510	2.9	25630	99310	3.9	13350	30950	2.3	81660	240890	2.9
1971	15950	47220	3.0	23800	77250	3.2	26970	151980	5.6	13580	44780	3.3	80300	321210	4.0
1972	17980	55990	3.1	21510	70660	3.3	28900	168480	5.8	14690	42380	2.9	83080	345510	4.1
1973	20500	82000	4.0	25000	125000	5.0	28000	217000	7.5	13500	54000	4.0	88000	478000	5.4
1974	13450	22000	1.6	26400	78200	3.0	23800	135400	5.7	9650	34400	3.6	73000	270000	3.7
1975	14300	31700	2.2	26800	115000	4.3	25100	175400	7.0	7800	39400	5.1	74000	361500	4.9
1976	17920	88760	4.9	33250	253790	7.6	36480	344260	9.4	9830	67710	6.8	97480	754570	7.7

[a] Area in hectares; production in quintals; yields in quintals/ha.

rusts in the coastal and subcoastal areas, and this may or may not be serious depending on the earliness of the disease outbreak. *Fusarium* species cause important diseases in lentil crops, especially as tolerance is low in local varieties. Root rot and powdery mildew are also fairly common diseases of field peas. In general, the level of disease infections and resulting yield losses is much higher in the moister environment of the coastal areas than in the dry interior where diseases are seldom a problem.

Of the insect pests attacking legumes in Algeria, bruchids, *Bruchus sp.*, are of prime importance. Seed damage in lentils, which are much more vigorously attacked than the other pulse crops, may reach as high as 40%; in chick-peas, broad beans, and field peas damage usually ranges between 15 and 30%. Also of importance are aphids, *Aphis sp.*, which are common pests of broad beans, lentils, and field peas, and which may become epidemic in some seasons.

At present no methods of control are being implemented for either the diseases or pests outlined above.

Weed infestation is by all standards the most important factor limiting legume production in the country, and different weed species are endemic to the whole range of arable land. Wild mustard, bindweed, pigweed, and lambsquarter are the most important broad leaf weeds, and the grass weeds that pose problems include wild oats, bromegrass, and ryegrass. Weed control mainly involves the use of cultivators or disc harrows to eliminate between-row weeds, but weeds growing within the row are not generally controlled. Chemical methods are thus being encouraged as a means of achieving more total control, but at present are only used on a very small scale. The use of Trifluralin as a preplanting control has been included as part of a package of production practices for full mechanization of lentil production, and it is hoped that this will result in about 10% of the food legume production area receiving adequate chemical control by the end of the 1979 cropping season.

Major Problems of Production

The failure of legume production to become a viable economic enterprise in Algerian agriculture has largely stemmed from the fact that farmers have no interest in large-scale production. This is due to the very low productivity under the existing production practices and the rising cost and scarcity of the necessary hand labour, especially at harvest time. Furthermore, the proven success and ease of mechanized cereal production systems has resulted in legume production becoming increasingly less popular with the farmers than the alternative cereal enterprises.

Apart from the labour problems, there are several factors that contribute to the prohibitively low productivity of legume crops in Algeria:

(1) Food legumes are generally grown on marginal land not easily accessible to machinery and unsuited to cereal production.

(2) Lack of chemical weed control and the high population of very competitive weeds necessitate planting the crops in wide rows to facilitate mechanical weeding. Fewer crops can thus be grown per unit area.

(3) Late sowing of lentils and chick-peas, low seed rates, and poor seedbeds frequently result in weak stands. The crops are highly susceptible to moisture stress, particularly when it is severe at flowering and pod filling.

(4) Absence of disease and pest control result in severe crop losses when conditions are favourable.

(5) Stresses, such as late frosts and dry (Sirocco) winds at critical crop growth stages, cause considerable yield reductions.

(6) Excessive postharvest manipulation and mishandling losses may reach as high as 20%.

(7) Lack of mechanization at sowing and harvesting reduces the timeliness of these operations, increases losses, and results in very high labour costs.

Research and Extension Support Available

The only organization engaged in field crops research in Algeria is the Institute for the Development of Field Crops (IDGC). This institute is responsible directly to the Ministry of Agriculture and Agrarian Reform and its work is carried out through two regional centres (East and West) and six experimental stations spread throughout the main agricultural zones of the country. The main work of the two centres involves extrastation experimentation and the coordination of the application and supply of agricultural technology, whereas the experimental stations are mainly engaged in crop improvement practices, which include hybridization on a limited scale, testing of selections, and the initial stages of seed multiplication. Agronomic experiments and variety trials are usually conducted over many locations in the country and are the responsibility of personnel working at the research centres. At present, research in food legumes is hampered by a lack of technical staff at all levels.

The extension of improved technologies is the responsibility of two organizations. First, there is the "Operation Integrée de Recherche et Développement," whose personnel are part of the IDGC and which operates mainly at the commune level. The organization's work involves conducting demonstration trials and field days to illustrate new techniques and technologies, and working closely with the farmers of the communes, helping them to adjust to the new machinery and the utilization of the new technologies generated by the research efforts. And secondly, there is the "Agrocombina," which is a new organization operating experimentally in only one district as yet. It combines agriculturalists, agronomists, and plant protection and machinery specialists in a group that operates at the farmer's level assisting groups of farmers in the realization of their annual production targets.

The multiplication and distribution of seed of improved varieties is also the responsibility of the IDGC. Breeders' seed and a large proportion of the certified seed is maintained at the research stations. Some certified seed and all registered seed is produced on IDGC selected farms under the supervision of IDGC personnel who issue certificates to the farmers involved. After laboratory analysis, the final certificate is granted and the seed stocks are stored and distributed by the Cooperatives of Cereals and Food Legumes under the supervision of the IDGC.

Current Research

Breeding and Varietal Improvement

International broad bean, chick-pea, and lentil material is tested at two locations, in the east and in the west of the country. The best types are then advanced to replicated trials in three locations across the country where detailed crop growth characteristics and yields are recorded. The lines performing considerably better than the local check varieties are advanced to 2nd and 3rd year replicated trials spread over more locations and the selection pressure is increased. At this stage, or in the 4th year, the best selections are tested in comparative trials on a large scale, under farm conditions in several locations in both the east and west of the country. A few lines are then selected on the basis of performance during the last 3 years and introduced into the seed multiplication cycle.

Agronomic Research

Eight dates of sowing, at 15-day intervals from 15 November, are currently being evaluated for the four crops in four locations. This experiment is designed to yield information on the optimum planting date for each crop in each location, together with details of crop response to environmental stresses, such as frost and drought. It is also hoped that the trial will provide an indication of the feasibility of growing lentils and chick-peas as a winter crop to avoid the severe drought stress often encountered at flowering and thereafter in spring-sown crops.

The world collections of lentils and chick-peas are also being screened in this connection to identify varieties adaptable to winter sowing, and many frost-resistant lines with good vegetative growth have already been identified.

Trials on population studies are also under way to ascertain the optimum and most economic combination of seed rate and plant spacing that will lend itself to total mechanization of the lentil, chick-pea, and field pea crops with the existing available farm machinery.

A study of the interaction between inoculation and fertilization in lentils and chick-peas aims to establish whether inoculation with specific rather than nonspecific *Rhizobia* has any effect on plant stand and grain yield. This study should also give information on the efficacy of nitrogen fertilizers applied early in the period of crop growth both in the presence and absence of *Rhizobia*.

A screening trial of 35 herbicides, to determine their effectiveness in the control of a broad spectrum of weeds and at the same time to evaluate crop tolerance to these chemicals, is also currently under way. The herbicides are being evaluated as applied at several stages: preplanting, preemergence, early postemergence, and late postemergence. Results to date are promising, indicating several chemicals that give 90% control of weeds with no noticeable effect on the crop.

Another trial on sowing methods for lentils is in progress to ascertain the effect of broadcast sowing as opposed to drilling on plant stand, productivity, and ease of combine harvesting. This is particularly important as the expertise of some farmers and the quality of some land makes it impossible to use seed drills well enough to arrive at a good plant stand.

The increasing interest in food legumes in Algeria, illustrated by its expanding research efforts, shows a more comprehensive understanding of the real problems limiting food legume production in the country than has hitherto been the case. A corresponding increase in the cooperation with other research efforts in the region will enable this base of research work to be considerably expanded and strengthened so that the important aim of promoting food legume production into the realms of an economic farm enterprise and thus achieving the desired expansion in production may be realized in the near future.

Production and Improvement of Grain Legumes in Egypt

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Food legumes are well known as rich and inexpensive sources of vegetable protein for human nutrition. In Egypt they play an essential role in the nutrition of the population, balancing the deficiencies of the basically cereal diet and supplying the bulk of the dietary protein requirements, especially to the people of the predominantly rural areas of the country. In addition to these nutritive considerations, legumes are particularly valuable in the agriculture of the country as, by virtue of their nitrogen-fixing capability, they are able to sustain high yields in the face of minimum inputs and at the same time improve soil fertility.

The legume crops grown in Egypt include: broad beans (Vicia faba), lentils (Lens culinaris), fenugreek (Trigonella feonumgraecum), chick-pea (*Cicer arietinum*), and lupin (*Lupinus termis*). Of these, broad beans are by far the most important, occupying over half the 500 000 acres annually devoted to legume production, and constituting a daily dish in the diet of most of the population. Lentils are secondary in importance, and chick-peas, although generally considered to be of minor significance, are becoming increasingly popular with growers due to the expanding market for their use in baby foods and other commodities.

Broad beans are cultivated throughout the country, with more emphasis on the regions of Middle and Upper Egypt (Fig. 1), and since 1950 their average yields have increased by about 39%, even though the area under cultivation has remained fairly static (Table 1). This reflects the considerable interest shown in the crop across the country and the consequently emphasized breeding efforts that have already culminated in the release of several varieties with better adaptation to the prevailing production conditions than local landraces. In contrast to this, both the area and production of lentils have declined considerably over the same period as a result of several major production constraints, which include unleveled soils, poor drainage, and severe waterlogging. These problems have arisen mainly as a consequence of the construction of the High Dam at Aswan and the introduction of canal irrigation into Upper Egypt where lentils are predominantly grown. The continuous decline in the annual acreage of legume crops, their sensitivity to climatic conditions, and the high and variable losses caused by pests and diseases are all contributing to the declining production situation, which is made all the more serious by the rapidly increasing population pressure.

Although some progress has been achieved in yield improvement, the total production of both broad beans and lentils is still below the local consumption requirements. This has meant that large quantities of both food grains are imported every year; in 1976, for example, imports of broad beans and lentils were 101 000 and 33 000 tons, or 28% and 46%, respectively, of total requirements.

Research Activities

Grain legumes are grown as winter crops of relatively short duration (sown in October/November and harvested in March/April) and usually in a 2-year rotation with

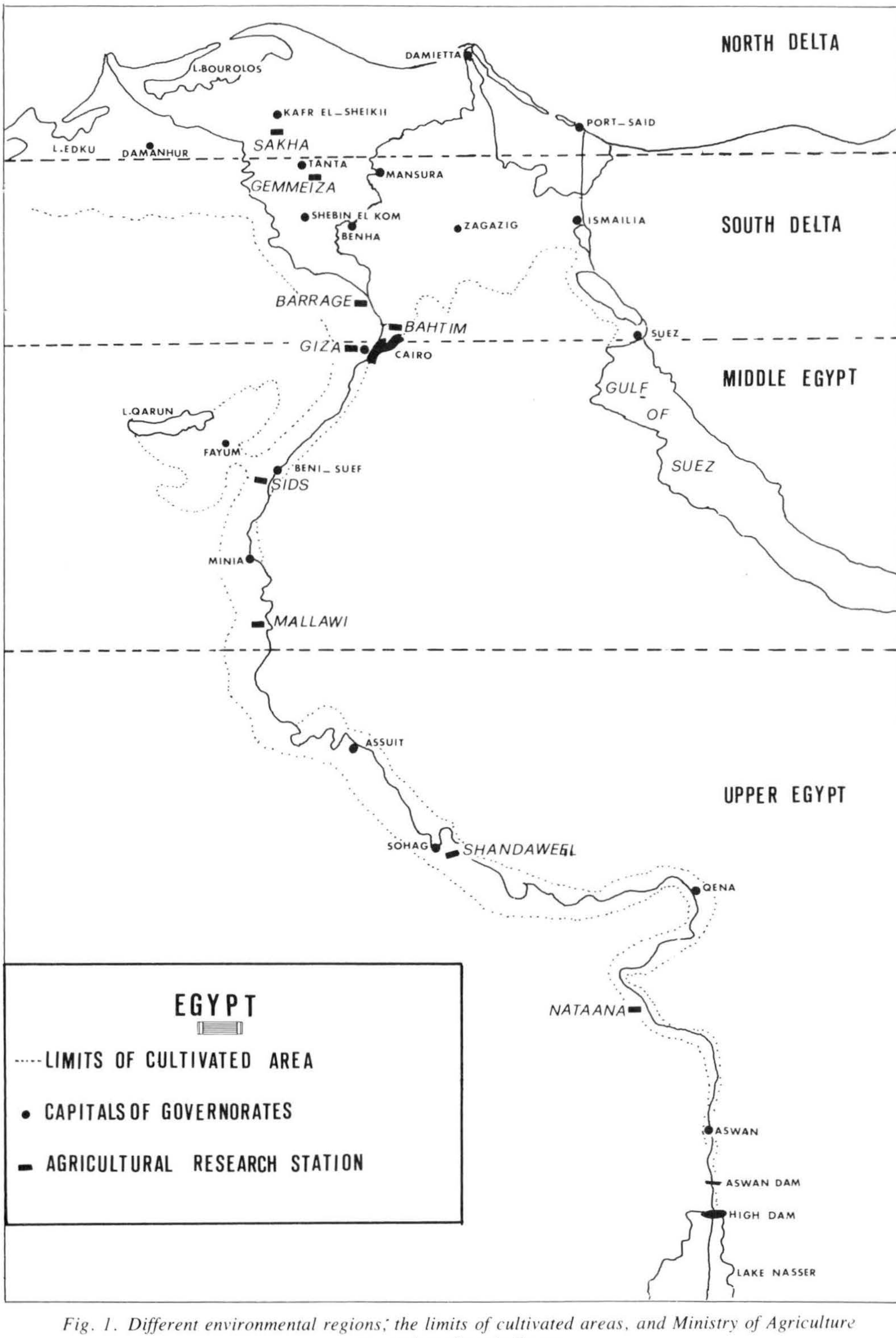

Fig. 1. Different environmental regions; the limits of cultivated areas, and Ministry of Agriculture research stations in Egypt.

TABLE 1. Average area ('000 feddans (1 feddan = 0.42 ha)), production ('000 metric tonnes), and yield (kg/ha) for broad beans, lentils, and chick-peas in Egypt during the 1950–1977 period.

	Broad beans			Lentils			Chick-peas		
Year	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1950–54	328	225	1631	74	47.5	1527	12.0	8.2	1617
1955–59	353	238	1605	80	48.0	1436	11.0	7.1	1525
1960–64	365	282	1837	77	48.0	1489	11.0	8.0	1650
1965–69	349	299	2037	65	39.7	1444	9.2	6.3	1639
1970–74	283	280	2361	64	50.1	1868	8.2	6.1	1759
1975–77	266	261	2265	57	33.8	1407	9.4	6.8	1726

either cereals or cotton. As it is difficult to increase the area under legume cultivation due to limitations on land reclamation and competition from other winter crops, research geared to increasing production in Egypt is primarily focused on increasing yield per unit area. This research is carried out at Ministry of Agriculture research institutes and stations throughout the country (Fig. 1), and consists mainly of breeding, agronomic investigations, varietal purification, and the propagation of foundation stocks.

Breeding

The major goals of the broad bean breeding program are the incorporation of resistance to the major pests and diseases (including *Orobanche*) and early maturity into stable and high-yielding varieties that have seeds of a high nutritive and cooking quality. For lentils and chick-peas, however, the main priorities are to produce early maturing varieties that are resistant to root rot and wilt diseases and adapted to production conditions in the Nile Delta area. The introduction of such varieties will pave the way for an expansion of the lentil and chick-pea acreages into this nontraditional production region.

Since the early stages of legume improvement work in Egypt, the dominating breeding procedure has involved selection in local populations and in segregating generations following intervarietal crosses (individual plant selection as part of a pedigree breeding system). The success of this effort was limited by the narrow germ-plasm pool of local landraces, which was insufficient to ensure a broad genetic base to the breeding efforts. However, this handicap has been largely eliminated as a result of the provision of a large germ-plasm collection of diverse geographical origin through the ALAD–IDRC–ICARDA regional cooperative legume improvement program initiated in 1972.

A number of entries of broad beans showing good resistance to chocolate spot and rust, the major diseases of this crop, have been identified from this material. Other varieties with high protein contents, lodging resistance, and/or desirable yield components have also been found. An expanded breeding program has been initiated to combine these attributes with the adaptation to the local environment shown by native cultivars. This scheme involves hybridization followed by compositing promising lines of early generations for cross-polination by honey bees to produce improved populations. The traditional pedigree and improved bulk selection breeding methods will, however, be retained to produce populations for use in hybridization and pure-line breeding.

An intensive crossing program is planned for the production of new lentil and chick-pea lines from this recently introduced material. This will be accompanied by further screening and testing of the introductions and selected material for resistance to root rot–wilt diseases and adaptability to production in the Nile Delta region. Promising material arising out of all these breeding efforts is included in a network of yield trials designed to evaluate its performance in the various different environmental regions of the country (see Fig. 1).

The breeding work to date has resulted in the release of the following improved food legume cultivars:

Crop	Cultivar	Special characteristics
Broad beans	Giza 1	Tolerant to chocolate spot and rust; adapted to North Delta region.
	Giza 2	Wide adaptability; recommended for South Delta and Middle Egypt areas.
	Rebaia 40	Adapted to Upper Egypt.
	Giza 3	Replacement for Giza 1.
	Giza 4	Replacement for Rebaia 40.
Lentils	Giza 9	Adapted to rainfed basin regions.
Chick-peas	Giza 1	Large seeded; recommended for the Delta and Middle Egypt areas.
	Family 2	Small seeded; Adapted to all regions.

Diseases

Chocolate spot (*Botrytis fabae*) and rust (*Uromyces fabae*) are the most serious yield-limiting diseases of broad beans in Egypt and are especially prevalent in the Delta regions. Crop losses can be as high as 50% when the diseases become epidemic, but annual losses normally vary from 5 to 20%. Chemical control using foliar sprays has been found to be effective in minimizing losses, and Dithane M 45 is now recommended for field control of both diseases. Delaying planting until early November has also proved useful in reducing crop losses, especially in years of severe infection. Considerable attention has, in the past, been directed toward disease control through resistant varieties, and special screening nurseries at Sakha and Nobaria, where both diseases are prevalent, have been used in an attempt to identify sources of resistance in segregating generations, new lines, and introductions. Some promising material has been found, but no very strong sources of resistance have yet been identified and hence progress has been slow.

The most serious diseases of both lentil and chick-pea are those of the root rot–wilt complex (*Fusarium sp.* and *Rhizoctonia sp.*), which can also be severe on broad beans. It has been found that losses from these diseases can be minimized by improving such agronomic factors as drainage, soil leveling, and crop water supply. A special nursery for screening broad bean, lentil, and chick-pea varieties for resistance to these diseases has recently been set up at Giza. This involves the creation of severe conditions in "sick plots" and it is hoped will lead to the identification of some promising material in the near future.

Pests

Broomrape (*Orobanche* sp.)

This parasitic weed presents serious problems in the production of all three major legume crops in Egypt. Some crops are so severely infested that large areas have to be abandoned every year, resulting in immense yield losses. Of the eight species of *Orobanche* recorded in the country, *O. crenata*, *O. ramosa*, and *O. aegyptiaca* have been found to be the most common and to cause the greatest amount of crop damage in the food legumes.

Although there are no totally effective methods for controlling this pest, late sowing (until the end of November), flooding prior to sowing, deep sowing, planting of trap crops (crops that stimulate *Orobanche* seeds to germinate but cannot themselves be parasitized, e.g., fenugreek, coriander, or flax) in the rotation, and planting after rice have all been shown to reduce levels of infestation.

Insects

Aphids (*Aphis lanurni*) are the most important field pests throughout the country and are considered to be one of the major factors limiting legume production in Egypt. However, they can be satisfactorily controlled through the judicious use of chemical pesticides.

Considerable losses of broad bean, lentil, and chick-pea seed are also caused in store by infestations of seed beetles (*Bruchus rufimanus*, *B. lentis*, and *B. incarnatus*).

Others

Birds, especially sparrows, present a major production problem and cause extensive crop damage at the flowering and early pod-filling stages. At present there is no effective control measure that can be recommended to combat this problem.

Agronomic Practices

One of the major constraints to increased production of food legumes in Egypt arises from the fact that these crops are grown under traditional and often suboptimal production systems. Considerable research emphasis is thus being placed on determining optimal agronomic criteria.

Sowing Date

Investigations over the past 3 years have indicated that the optimum sowing date for broad beans varies with variety and location; Giza 2 and Rebaia 40 are best sown around mid-October in Middle and Upper Egypt, whereas the optimum time for planting Giza 1 in the North Delta is early November. Late sowing is to a certain extent recommended in these Delta regions for control of chocolate spot rust and *Orobanche*, which are widespread.

For lentils and chick-peas, studies have established the optimum sowing date to be during the first 2 weeks of November.

Population Density

The majority of broad beans grown in Egypt are produced on ridges to facilitate agronomic operations. Extensive research on ridge width, hill spacing within ridges, and number of plants per hill has established that the optimum population density for the existing varieties varies between 80 and 85 plants/m^2 (320 000–340 000 plants/acre). This may be achieved by sowing two plants per hill, on hills 20 cm apart on either side of ridges spaced at 60 cm.

All lentil seed is broadcast sown in Egypt using relatively high seed rates. Studies have shown that, although yield increases slightly with every increase in sowing rate, the optimum seed rate ranges from 35 to 45 kg/acre when broadcast into a well-prepared seedbed and followed by good leveling. Investigations on other methods of planting have indicated that the highest seed yield of lentils may be obtained by sowing 30 kg of seed per acre into ridges 60 cm apart.

The standard population density for chick-peas, used by farmers and research stations alike, is between 28 and 30 plants/m^2. However, the results of a 2-year study indicate that yield/acre increases progressively and significantly with increasing plant population up to 840 000 plants/acre. Further studies are required to determine an optimum density.

Irrigation

Results of studies on broad beans conducted at three locations representing the different environments of the country have shown regional differences between the optimum number and timing of irrigations. No significant differences were detected between treatments in the North Delta, and this can probably be attributed to the higher rainfall of this region. However, alterations in the watering regime in Middle and Upper Egypt resulted in considerable yield differences. Based on these and other results, the recommended irrigation pattern for broad beans in Middle and Upper Egypt involves four irrigations at 30-day intervals from the time of sowing. In the Delta regions, where a certain amount of rain may be received and increasing the irrigations has little effect on net yield, the necessity of chocolate spot and rust control has meant that a minimum number of irrigations are recommended.

The only commercial variety of lentil available in Egypt is Giza 9, which is adapted to nonirrigated basin land production in Upper Egypt. This variety is very susceptible to overwatering and thus, although water stress commonly results in low yields, most farmers do not irrigate for fear of causing severe crop damage. Investigations into the optimum watering regime for this variety have determined that two or three irrigations will give significantly higher yields providing that the seedbed is level and well prepared and the distribution of seed and irrigation is accurate. Much of Upper Egypt has come under perennial irrigation as a result of the construction of the High Dam, and, as a result, considerably more research needs to be done to produce lentil varieties less susceptible to overwatering to enable production in this traditional area to continue at its former level.

Fertilization

In general, Egyptian soils suffer from very low levels of both nitrogen and phosphate. In recognition of this, considerable research efforts have been directed toward ascertaining the effects of artificial fertilization on the legume crops.

Crop response to nitrogen applications of 36 kg/ha varied from a 10.5% yield increase in broad beans to a 6.2% increase in lentils. Applications of phosphate at a rate of 72 kg/ha caused a 15.7% increase in the yield of broad beans, but only about half this figure in lentils. Optimum yields of broad beans were obtained with applications of 36 kg N and 72 kg P_2O_5 per hectare, and applications of 18 kg N and 72 kg P_2O_5 to lentil crops were found to be the most economical.

Weed Control

Weeds compete strongly with the growing legume crops for both water and nutrients, and control is thus essential for efficient production. Manual methods of cultivation are still the only available means of carrying out this task in most of the legume-producing areas. To keep the fields clean, cultivation must be repeated three or four times during the growing season and this makes legume production very labour-intensive. With labour costs rising fairly rapidly, it is becoming increasingly urgent to develop other less labour-intensive control procedures.

Harvesting

Legume crops set their pods over a fairly prolonged period of time, and the pods consequently ripen rather unevenly. This makes harvesting difficult as not all the pods will be at the same stage of ripeness at any one time. To minimize harvesting losses, the plants have to be reaped before the pods are completely dry and left to mature in the field. It is advisable to harvest these crops early in the morning to avoid undue shattering, which becomes serious as the plants dry out in the heat of the day. Investigations have shown that the interaction between sowing and harvesting dates have a highly significant effect upon seed yield. It has been concluded that, if the legume crops are sown at the recommended optimum dates, harvesting may be carried out most efficiently after 140–152 days, 115–120 days, and 140–150 days for broad beans, lentils, and chick-peas, respectively.

Seed Quality and Multiplication

Seed samples of broad beans and lentils from various trials are routinely analyzed for protein content and cooking quality as part of a seed quality program. Results to date indicate that, within local material, locality rather than variety had the most effect upon seed quality as measured by these two criteria. However, there appears to be considerable variation in protein content within the material furnished by ALAD–ICARDA, and new facilities provided by IDRC should assist in developing an effective seed quality research program around this material.

The maintenance, purification, and distribution of seed of new varieties developed in Egypt is the responsibility of two organizations: the Grain Legume Section of the Field Crops Research Institute ensures the multiplication and supply of the breeder's, foundation, and registered seed in seed increase areas at the Ministry of Agriculture's experimental stations and farms; and the Seed Department of the Ministry of Agriculture has the responsibility for the production, inspection, testing, and distribution of certified seed to the producers.

Major Constraints to Legume Production

The work of the research department outlined above is directed toward providing solutions to the critical problems that at present limit the production of food legume crops in Egypt. These constraints may be summarized as follows:

- the lack of physiologically efficient, high-nodulating, and disease- and pest-resistant varieties, resulting in low crop productivity;
- the considerable gap between yields of varieties in experimental plots and the national average yield under production conditions, which may reflect a number of the agronomic factors outlined below;
- problems of soil salinity associated with poor drainage and bad water management and

the continued use of manual operations in land preparation, weeding, harvesting, and threshing, which are time consuming, costly, and result in considerable yield losses, rather than the more efficient mechanical methods; and

- the small average size of land holdings, which makes it difficult to effectively utilize improved production technologies.

Despite the considerable progress already made through the research efforts of the country toward solving these and other production problems, the further potential for considerable increases in yield, disease resistance, and nutritional quality is well recognized. The program, in close collaboration with other organizations in the region, is actively working toward the realization of this potential both through the improvement of yielding ability and through work designed to raise the productivity of newly reclaimed land, together with the development of varieties suited to the different conditions of these nontraditional areas of production.

Food Legume Production in the Hashemite Kingdom of Jordan

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Jordan has a classically Mediterranean climate, characterized by warm dry summers and mild winters, during which all the annual rainfall is received. Agroecologically, the country can be divided into three major zones: the Highlands with an annual rainfall of between 300 and 700 mm; the Jordan Valley, which receives about 250–350 mm of rainfall per year; and the Eastern Desert, where the rainfall seldom exceeds 100 mm.

Agriculture is the basic industry of Jordan, constituting about 30% of the gross national product. Of the total land area of the country, 13.3% is arable and, of this, 89% is devoted to the cultivation of winter cereals, mainly wheat and barley. Grain legumes occupy the bulk of the remaining 11%, or 28 000 ha of land concentrated in the northern and central highlands, where annual precipitation ranges between 300 and 450 mm (Fig. 1).

Lentils, chick-peas, and broad beans (fresh and dry) are the major food legumes grown, and the area, production, and yield of these crops for the 5-year period 1973-77 are given in Table 1. Although yield and production are erratic and generally low, there is considerable variation between the major production regions, the northern district of Irbid being the most important production area and together with the Amman district producing the highest yields. The extreme fluctuations in both crop area and yield can be attributed almost entirely to the erratic rainfall and traditional production methods used in the country.

Utilization and Marketing

Despite exports of lentils amounting to 10 000 tonnes in some years, Jordan may be considered a net importer of legume grains. With current market prices of $600/tonne for lentils and $700/tonne for broad beans, there is an increasing interest in expanding pulse production in the country, both for import substitution in the case of broad beans and as a means of increasing export earnings from lentil production. Classically, legume grains are considered to be a good substitute for animal protein in the diets of the poorer sections of the population; however, improved production and transport facilities have made red and white meats available to a large part of the populus, and legumes are now increasingly used as supplementary protein sources, both as dry seed in the case of lentils and chick-peas, and as dry and green seed in the case of broad beans. A canning industry is now evolving in support of chick-pea and broad bean production and distribution.

Production Practices

Food legume production in Jordan is carried out on very traditional lines. The pulses are part of an established 3-year rotation with cereals, and seedbed preparation is minimal.

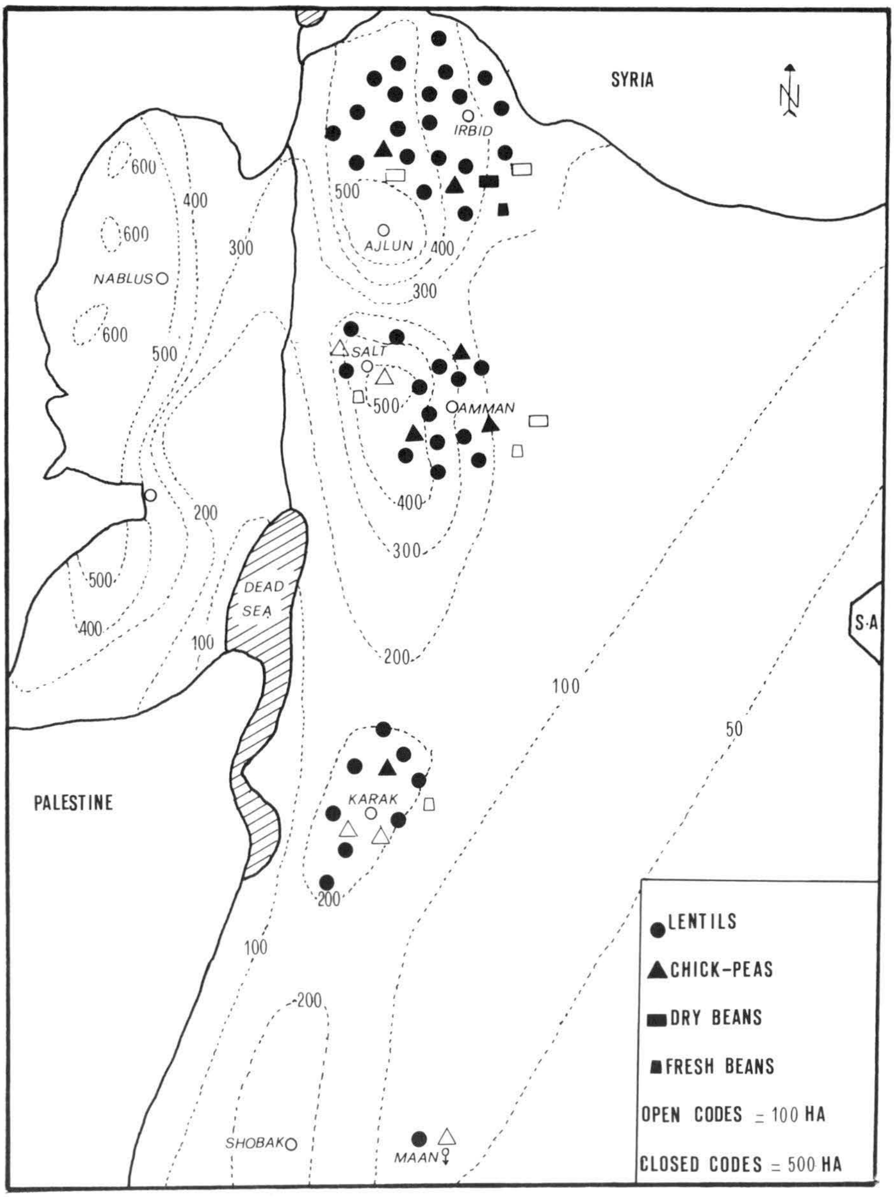

Fig. 1. Distribution of grain legumes in Jordan with reference to mean annual precipitation.

Lentils are broadcast by hand at a rate of about 100–120 kg/ha in the period mid-December to mid-January and covered by a shallow plough. Chick-peas and broad beans are also hand-seeded, but into a furrow opened with a local plough, the seed rates being 80–100 kg/ha and 60–80 kg/ha respectively. Rhizobial inoculation is not practiced and no fertilizers are applied to the crops. Harvesting in May/June is predominantly by hand, and the crop is left out in the field to dry before being threshed from the haulm by animal-drawn threshing boards or local threshers.

The problems of food legume production, which cause severe limitations on the more widespread cultivation and increased production of these crops, stem from the fact that all

TABLE 1. Area (ha), production (metric tonnes), and average yield (kg/ha) of the major legume crops in Jordan in the period 1973–77.

	Lentils			Chick-peas			Broad beans[a]					
							Area		Prod.		Yield	
Year	Area	Prod.	Yield	Area	Prod.	Yield	D	F	D	F	D	F
1973	18250	4490	246	3964	2579	651	679	896	370	7205	545	7253
1974	21802	21596	991	5662	3792	1023	1135	848	1290	7519	1488	9640
1975	22229	10476	471	3341	928	129	812	1337	240	16516	296	10025
1976	25016	10873	435	1892	778	42	793	987	482	7149	608	7243
1977	16179	7377	456	3216	1545	258	–	–	–	–	–	–[b]

[a] D = dry seed; F = fresh beans.
[b] Figures for 1977 broad bean area, production, and yield were not available at time of writing.

the production processes are carried out in the traditional ways. Improved technologies related to high-yielding and stable cultivars, cultural practices, and mechanization have not been applied to the pulse crops as yet. With the cost of labour rapidly becoming an inhibiting factor to legume production, the evolution of such technologies and their application to the real situation is now becoming a matter of urgency if the present level of production is to be maintained or increased in the future.

Research Activities

Research on food legumes is carried out mainly by the Ministry of Agriculture, at their experimental stations, and the University of Jordan's Faculty of Agriculture. A recent survey and collection of local germ plasm together with material provided by ICARDA has enabled a selection program aimed at identifying genotypes with improved yielding abilities under the local environment conditions to be initiated. Alongside this, investigations into crop agronomy, cultural practices, and improved production techniques (viz. mechanization) are also currently under way. Priorities should be given to the expansion of research activities and the establishment of a firm base to seed multiplication and distribution in the country so that the popularity of grain legumes can be increased to take advantage of the favourable market conditions that exist for pulse products at the present time.

Food Legume Production and Improvement in Iran

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The total land area of Iran is about 1.6 million km², of which only 17.48 million ha are under cultivation. Because a large amount of land is left fallow every year, the annual cropped area is only approximately 11.288 million ha and the area devoted to the production of food legumes is about 423 000 ha per year, or 3.7% of the cropped area.

Due to its geographic location, the country experiences a very wide range of climatic conditions, ranging from very cold and arid in the northern mountainous areas to hot, tropical and subtropical climes around the Persian Gulf and the Oman Sea in the south. From an agroecological standpoint, Iran can be divided into a number of characteristic zones (Fig. 1):

(1) the Caspian Sea area, in the north, which has a very high annual rainfall, varying from 700 to 1200 mm; broad beans and dry beans are the main legume crops produced;

(2) the mountainous regions of the northwest and northeast, with high elevations and 350–500 mm annual precipitation, where the major legume crops are lentils, chick-peas, and dry beans;

(3) the Central and Eastern Plateau, stretching from the mountain ranges to the desert areas. The precipitation varies from 250 mm in the vicinity of the mountains down to less than 100 mm near the deserts. Chick-peas, lentils, cowpeas, dry beans, and mungbeans are the main legume crops;

(4) the southwestern plains of Khouzistan, which have a very hot and humid summer climate and an annual rainfall of about 200 mm and where broad beans, dry beans, cowpeas, and mungbeans predominate among the legumes;

(5) the south and southeast of the country, where precipitation is very low and the climate is hot and dry in the summer period. The most important food legume crops are mungbeans, dry beans, and broad beans.

Of the total pulse production area, approximately 69.5% is rainfed and 30.5% irrigated. The area, production, and yield of the main legume crops are given in Table 1. The very low average yields of pulse crops in Iran reflect the wide range of conditions under which they are grown and the difficulty of obtaining and recommending varieties and agronomic practices to fit these very varied ecological niches.

Utilization and Production

Grain legumes provide a very useful source of protein to the diets of the population of Iran and are used mainly as dry seeds, with the exception of broad beans and dry beans, which are also consumed as green seed. In addition, the by-products of seed production, the pods and plant haulms, provide a very valuable animal fodder.

Chick-peas and lentils, the two most important pulse crops in the country, are predominantly grown in the mountainous regions under rainfed conditions where they are rotated with a cereal crop (wheat, barley, or rye) and a fallow period. The crops are normally sown from March to late April and the harvesting season extends from mid-July to mid-August.

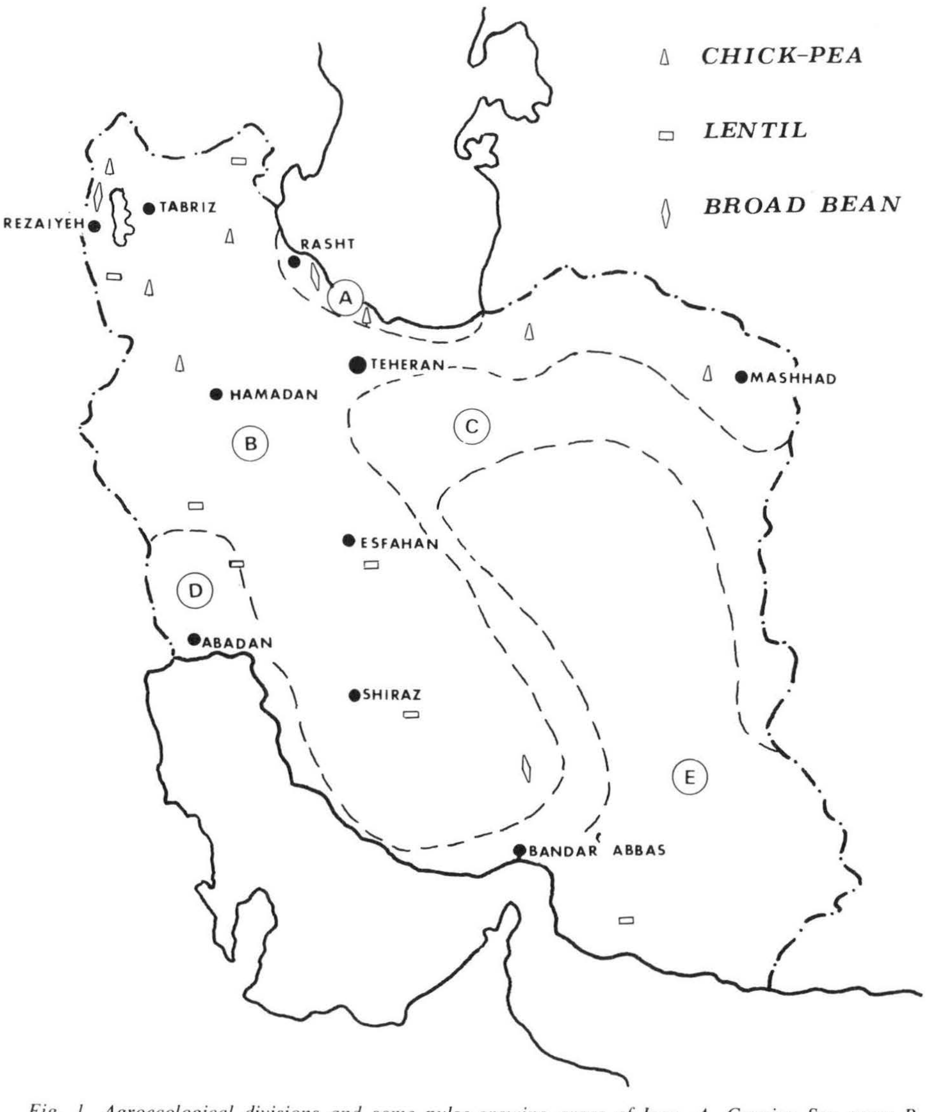

Fig. 1. Agroecological divisions and some pulse-growing areas of Iran. A, Caspian Sea area; B, mountain region; C, Central and Eastern Plateau; D, Khouzistan Plains; E, dry south and southeast.

TABLE 1. Estimated area ('000 ha), production ('000 metric tonnes), and average yield (kg/ha) of legume crops in Iran.

Crop	Area			Production	Avg Yield
	Rainfed	Irrigated	Total		
Chick-peas	236	57	293	149	508
Beans (incl. cowpeas)	3	36	39	48	1231
Lentils	45	2.5	47.5	22	483
Mungbeans	–	25	25	12.5	500
Broad beans	9.9	8.6	18.5	23.2	1250

Dry beans, cowpeas, and broad beans are grown throughout the country, and with the exception of production in the Caspian region, are cultivated under irrigation. The high rainfall of the Caspian region enables these crops to be produced without supplementary watering. In this area they are grown in rotation with rice and are planted between late March and mid-May, depending on climatic conditions. In the Central Plateau areas and the south and southwestern parts of Iran, where production involves irrigation, the planting seasons are late April to late June and late December to early February respectively. Harvesting of green pods commences 2½–3 months after planting and of dry seed 1½ months after this, the season being very extended as a result of the wide range of planting dates.

Mungbeans are grown in very small plots and often follow cereal crops in a rotation. Planting starts from early June in the Central Plateau to mid-July in the Khouzistan plains, and the harvesting season extends from late September to late October.

Diseases

The two diseases of major importance to chick-pea production in Iran are chick-pea blight caused by *Ascochyta rabiei* and root rot caused by *Rhizoctonia solani* and possibly also *Fusarium* and *Pythium* species. Both these diseases cause severe yield losses in the main chick-pea producing areas. Fungicides such as Captan, Dyrene, Benlate, and Zineb have been found to give good control of blight, and seed treatment with Thiabendazole or Benlate is effective in reducing root rot infections.

Root rot is also a major problem in dry (*Phaseolus*) beans, where, together with bean common mosaic virus (BCMV), it causes considerable damage to the crop. Fortunately bean varieties with varying degrees of resistance to these diseases have been found and are at present being used in the production of resistant cultivars as a control measure.

Viruses are also the main disease-causing organisms in cowpeas (common aphid-transferred mosaic virus (CAMY)), broad beans (bean yellow mosaic virus (BYMV)), and mungbeans (BCMV and BYMV). Viral diseases are very damaging and cause considerable yield reduction. They are especially important in the broad bean crop. Although some resistance to CAMV has been found in cowpeas and is being used in the production of hybrid varieties, no resistance to BYMV has yet been discovered in broad bean lines.

Pests

Aphids, which include the green aphid (*Acyrthosiphon sesbaniae*), the broad bean aphid (*Aphis fabae*), and the chick-pea aphid (*Therioaphis trifolii*), are very damaging to all the pulse crops, both as a result of their infestation and due to their virus transmission abilities. Army worms (*Laphgma exigua*) are also a major pest of all the legumes.

Chick-peas are specifically affected by pod borers (*Heliothis armigera* and *H. dipsaceae*) and the seed corn maggot (*Hylemia cilicrura*), which may cause considerable crop losses under favourable conditions.

Other important field pests include the chick-pea fly (*Liriomyza congesta*) and thrips (*Thrips inpurus*) on lentils; leaf hopper (*Empoasca fabae*), striped beetle (*Agriotis* sp.) and spider mite (*Tetranchus bimaculatus*) on beans; and bean butterfly (*Lycaena baeticae*) on cowpeas.

Cowpea beetle (*Callosobruchus maculatus*) and lentil beetle (*Bruchus lens*) are important pulse storage pests and can result in considerable losses in seed quality as well as quantity.

Each of these pests has been studied in detail and appropriate control measures developed through pesticides, cultural practices, and, in some cases, particularly in cowpea storage pests, through the evolution of resistant varieties.

Research Activities

With the cooperation of the Ministry of Agriculture, the Planning Organization, USDA, and the University of Tehran, the Pulse Improvement Project was established at the

Karaj College of Agriculture in 1965. The main objective of this project is to produce high-yielding, good quality, disease-resistant varieties together with improved practices for their production. Since its inception, the project has built up a germ-plasm collection of over 12 000 lines of the major pulse crops in Iran and has produced and released over 17 improved varieties of chick-pea, lentil, cowpea, dry bean, and mungbean for production throughout the country. Varietal development has been geared mainly to cultivation under irrigation and it is estimated that 20 000 ha of land are now annually sown to these varieties, which yield two or three times the level of the traditionally grown types.

Experiments and tests are carried out at Karaj, in the experimental stations of the Ministry of Agriculture throughout the country, and at various other Agricultural Colleges, to ensure that the investigations are appropriate to the wide range of climatic conditions that exist within Iran. In this way, agronomic research, in support of varietal development, to determine crop water requirements, fertilizer needs, optimum planting dates, and planting densities and other cultural practices and requirements is being carried out across the country. Such work aims to promote the production and spread of the pulse crops, which play such an important role in the nutrition of such a large part of the population of Iran.

Food Legumes in Iraq

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The Iraqi climate is continental and arid, with temperatures reaching 47 °C in summer and dropping to −1 °C in winter. The annual rainfall, which is concentrated between the months of October and May, ranges from 50 to 1200 mm across the country. On this basis and from its overall agroecology, Iraq can be divided into three main zones:

(1) the mountain region, where the annual rainfall of 600–1200 mm falls mainly as snow and where temperatures are extreme; the soils are brown and chestnut lithasols and are subject to considerable erosion; food legumes are, in general, not grown in this region;

(2) the dryland farming region, in which rainfall varies between 250 and 500 mm and temperatures are less extreme; in the upper plains, the soil lacks organic matter, but in the steppe areas it is deep and fertile and well suited to the rainfed cultivation of chick-peas, lentils, and broad beans;

(3) the central and southern region, which includes a large part of the Tigris and Euphrates Valley, with rainfall averaging only 50–150 mm per annum; the soil is mainly silty clay loam to clay loam with a high pH, and legumes such as broad beans, peas, blackeye beans, and green gram are grown under predominantly irrigated conditions.

The area production and yield of the food legume crops vary between regions (Table 1).

Utilization and Marketing

Food legumes are predominantly utilized for human consumption in Iraq, and are eaten as green pods (broad bean, cowpea, and *Phaseolus* bean), green seed (broad bean and pea), and dry seed (chick-pea, lentil, broad bean, cowpea, and green gram). In addition, some crops, such as green gram, are used for pasture and as a green manure, and crop residues from grain production provide a valuable fodder for livestock.

All pulses are produced for the domestic market and there is no exportation of these commodities. Prices are unstable and vary over time as a result of variations in supply and demand. However, the prices paid to producers are fixed by the government each year and this lends some stability to the market. Prices (in Iraqi dinars/tonne (1 Iraqi dinar = ca. U.S. $0.035)) for 1978 are as follows:

Broad beans	Green pods	80
	Dry seed	150
Cowpeas	Dry seed	250
Lentils	Dry seed	150
Chick-peas	Dry seed	140
Green gram	Dry seed	160

TABLE 1. Area (ha), production (metric tonnes), and average yield (kg/ha) of the major pulse crops in Iraq, 1973–77.

	Broad bean						Lentil			Chick-pea			Cowpea			Green gram		
	Area		Prod.		Yield[b]		Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
	I[a]	R[a]	I	R	I	R	R	R	R	R	R	R	I	I	I	I	I	I
1973	32710	8935	103521	18779	880 (5200)	760 (5200)	4271	2425	568	8291	4515	544	9703	35000	804	9495	7216	760
1974	28650	8750	126946	20200	1040 (4800)	920 (3600)	3983	2573	648	9555	5296	556	8341	26770	870 (4404)	13958	9216	660
1975	34521	8400	126946	20200	1000 (6000)	800 (4000)	5140	4819	936	11411	7494	656	6341	26798	1016	13071	6887	528
1976	26575	8500	72801	24267	1000 (6000)	880 (4200)	5654	5204	920	13675	7180	525	6565	28160	858 (4520)	11331	7643	680
1977	33800	7512	154810	24931	1120 (6400)	920 (4000)	6335	5919	928	15000	9165		8727	38911	4760	8000	5422	676

[a] I = irrigation; R = rainfed.
[b] Unbracketed = dry seed yield; bracketed = green pod yield.

Production Practices

The production of pulses in Iraq relies mainly on the traditional techniques of cultivation. Chick-peas and lentils are grown in rotation with cereals in the northern dryland farming areas of the country, while government farms are developing different rotations under irrigated conditions for broad beans and green gram. All tillage involves traditional implements and the seed is broadcast in the case of chick-peas, lentils, and green gram, or hand planted in furrows in the case of broad beans, cowpeas, and peas. Broad beans and lentils are winter sown, generally being planted in November at seed rates of 120 kg/ha and 60–80 kg/ha respectively, whereas chick-peas, cowpeas, and green gram are summer crops sown from March, in the case of chick-peas, through to July. Chick-peas are sown at 60–80 kg/ha and cowpeas and green gram at 30 kg/ha. Only local unimproved varieties of all these crops are used. Although fertilizers are not normally applied by the farming community, government farms usually add about 200 kg/ha of ammonium sulfate and 100 kg/ha of superphosphate to their crops.

Pests and Diseases

The diseases of pulse crops of major importance in Iraq include rust (*Uromyces phaseoli*), leaf blotch (*Alternaria* sp.), and wilt (*Fusarium* sp.). Considerable yield losses can result from infections of these pathogens, and control measures in use and being developed involve an integration of resistant varieties with chemical and cultural methods.

Black bean aphid (*Aphis fabae*) is the single-most important insect pest affecting grain legumes throughout the country, causing damage from viral transmission as well as from its own infestation of the plants. Control is achieved through the use of Malathion and Fapoma sprays.

Despite favourable soil and climatic conditions, the production of grain legumes in Iraq is beset by several major problems that at present prevent any real expansion. These problems are based around the lack of improved varieties with higher yields, pest and disease resistance, and adaptation to the Iraqi environment, and the untimely and costly traditional production practices involving a high labour input. The high and increasing cost of manual labour and its scarcity at peak times are making the problems considerably more acute and are currently emphasizing the necessity for substantially expanded research efforts aimed at introducing new varieties and production technologies suited to the conditions of the country.

Research Activities

In appreciation of this need, a Legume and Forage Division has recently been added to the Field Crops Section of the Department of Research. This division is involved with the development of new varieties from selections made from local and introduced legume material and the evolution of agronomic practices suited to their widespread production. Specifically the work to date has involved screening nurseries received from FAO, the regional centre for legumes in Tehran, and other research institutes in the region; conducting yield trials on the promising lines identified in these nurseries; and establishing, through experimentation, optimum dates of planting, plant populations, and rates of fertilization. Although no breeding work has yet been undertaken, it is hoped to initiate several crossing programs in the near future.

With both weather and soil being well suited to the large-scale production of a wide variety of legume crops, the provision of improved varieties and appropriate mechanization for the main operations of sowing, weeding, harvesting, and threshing will enable the cultivation of grain legumes in Iraq to expand considerably. For this reason the legume and forage research program is looking toward expanding its activities through increased cooperation with research institutes throughout the region to provide technical training for its personnel and to interact with specialists from all over the region who are working with and toward solving the same critical problems.

Food Legume Research and Development in the Sudan

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The Sudan, with the exception of the Red Sea hills, lies within the region of summer rainfall. The rains last for up to 9 months in the far south of the country where the total annual rainfall may reach 1500 mm, but the length of the season shortens and distribution becomes more erratic as one moves northward, precipitation being practically zero in the northern-most parts. Temperature conditions are correspondingly more extreme in the north, which may remain relatively cold for 3–4 months of the year. The cool winters and their long duration in these parts of the country (the Northern and Nile provinces, Fig. 1), coupled with the availability of irrigation water from the river Nile, permit the production of winter crops, which include broad beans, haricot beans, chick-peas, lentils, lupins, field peas, and berseem. Of these crops, broad bean (*Vicia faba* L.) is the most important, occupying 60% of the pulse acreage, followed by haricot bean (*Phaseolus vulgaris* L.), chick-pea (*Cicer arietinum*), and lentil (*Lens culinaris*) (see Table 1).

Broad Bean (*Vicia faba* L.)

Broad bean is grown as an irrigated crop in Northern Sudan and its cultivation is limited to the zone between latitudes 13°N and 22°N, primarily around the cities of Dongola, Berber, and Shendi (Fig. 1). An estimated area of 30 000 feddans (1 feddan = 0.42 ha) is cropped annually but yields vary greatly between years depending on climatic conditions.

Agronomic Aspects

The recommended sowing time is between mid-October and early November. Planting earlier than this causes considerable losses due to infections of wilt and root rot diseases soon after planting, the prevalence of which increases with temperature. Late-sown crops also suffer and those sown in December may give no yield at all due to high spring temperatures coinciding with flowering and causing a large amount of flower shedding. Many experiments have been conducted at the Hudeiba Research Station to investigate the effect of seed rate and spacing on broad bean yield. Results of these studies have shown that very large variations in plant population have little effect on grain yield due to the compensatory nature of its components. Large-seeded varieties (e.g., Rebaya 34) have been found to emerge earlier and produce larger plants than small-seeded types such as Baladi; however, this phenomenon has not been effectively translated into appreciably superior seed yield due to the relatively faster growth rates of the small-seeded varieties.

Considerable experimentation has yielded conflicting information on the effect of fertilization on broad bean seed yield: responses to fertilizer application range from zero to 23% increases in different investigations. The inconclusiveness of these studies has led to increased interest in rhizobial inoculation as a means of increasing seed yield. Inoculation with a Sudanese strain of *Rhizobium* has produced increases of 18% in the early nodulation

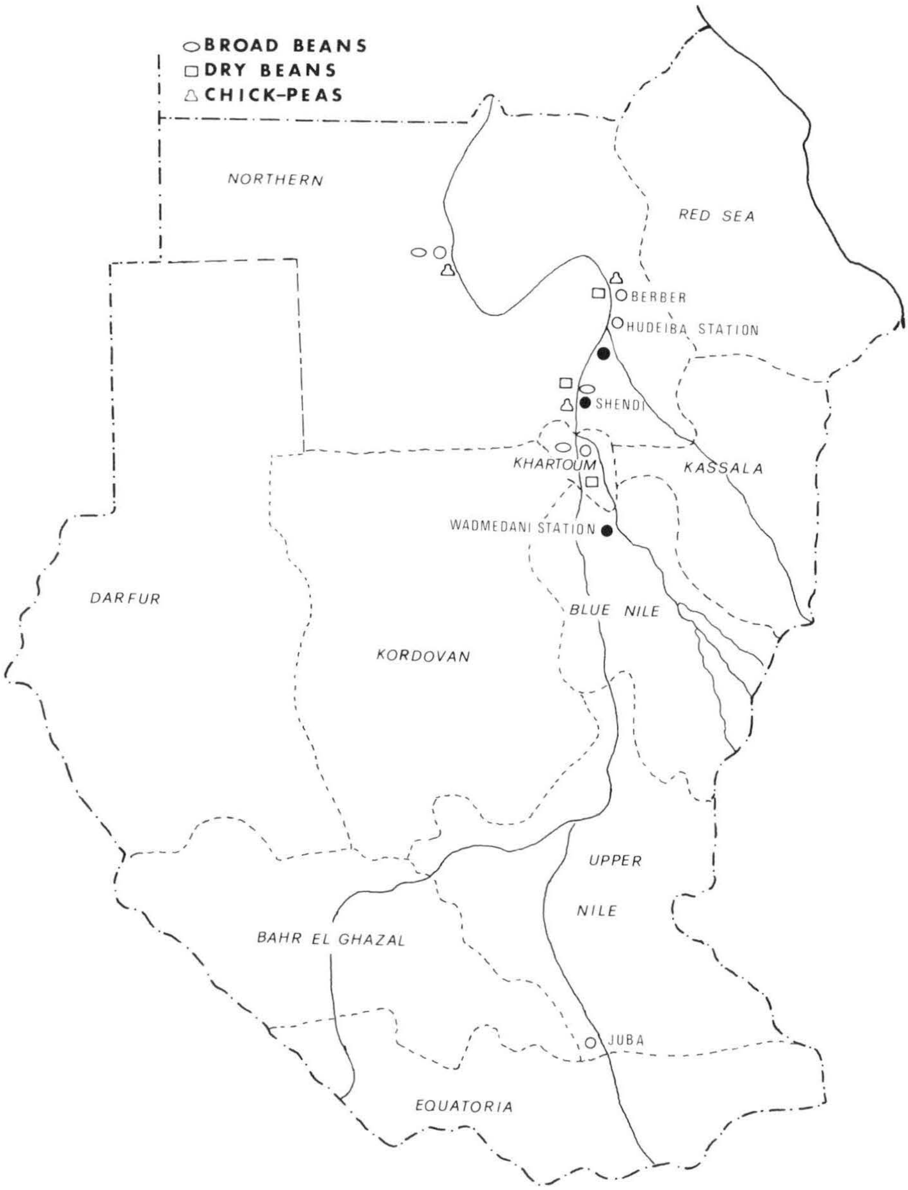

Fig. 1. Main legume production areas of Sudan. ●, research stations, main production areas.

of plants, but the use of a French strain has been found to reduce nodulation. Nitrogen application has been shown to reduce nodulation in both strains, affecting the French type more than the native Sudanese type.

The high temperatures prevailing during the growing season have a considerable effect on the moisture regime of the plants, producing appreciable water stress at certain stages. Research has indicated that the frequency of irrigation is of great importance in minimizing this stress. A watering interval of 5 days gives significantly higher seed yields than longer intervals, and increasing the interval of watering at pod formation from 7 to 14 and 21 days has been shown to decrease seed yield by 36 and 76%, respectively. This appreciable effect may be due to the fact that water infiltration is slow as a result of soil type, and hence evaporation may be considerable.

TABLE 1. Total area (in '000 feddans[a]) and total production (in '000 metric tonnes) of broad bean, haricot bean, and chick-pea in the Sudan from 1967 to 1977.

Crop year	Broad bean		Haricot bean		Chick-pea	
	Area	Prod.	Area	Prod.	Area	Prod.
1967–68	22.9	13.0	9.5	3.8	8.7	1.9
1968–69	22.6	11.3	7.5	2.5	3.5	1.6
1969–70	22.7	15.6	7.8	4.0	4.4	0.8
1970–71	27.2	18.8	8.4	4.2	4.8	4.9
1971–72	43.7	38.1	7.9	4.9	4.8	2.0
1972–73	27.8	17.3	6.3	4.0	–	–
1973–74	35.0	20.6	8.0	4.4	3.0	0.9
1974–75	38.0	29.0	11.8	12.0	3.6	1.4
1975–76	35.9	30.7	11.6	9.3	6.5	2.6
1976–77	33.4	24.6	9.0	6.3	–	–

[a] 1 feddan = 4200 m^2 = 0.420 ha = 1.0379 acres.

TABLE 2. Effect on seed yield and yield components of harvesting broad beans at different stages of maturity, in the Sudan.

Age of plant at harvest (days)	Seed yield (*kg/feddan*)		Yield components (1977)		
	1976	1977	T.S.W.[a] (g)	Pods/plant	Seed/pod
80	–	492	262	18.3	2.5
90	245	604	271	19.8	2.1
100	578	934	355	21.2	2.5
110	918	993	398	19.0	2.6
120	902	904	389	21.5	2.6
130	753	–			
140	683	–			

[a] T.S.W. = thousand seed weight.

Some farmers in the north of the Sudan harvest their broad bean crop after only 80 days, with the aim of getting high prices at the time of lowest supply. However, it has been found that the difference in price obtained will not compensate for the yield reduction due to early harvesting. Investigations have indicated that the highest seed yield can be obtained by harvesting at 110 and 120 days after planting, but this of course will vary with the environmental conditions of the season (Table 2).

Infestations of weeds also result in substantial yield reductions in broad beans. Weeding has been traditionally carried out by hand, but because of the increasing cost of labour there is now an urgent need to investigate alternative control measures.

Varietal Improvement

Selection

Broad bean breeding work was initiated in 1961–62, with selections from Rebaya 40 and Baladi varieties, to identify tolerance to powdery mildew combined with earliness and a high yield potential. Selection and testing in 1963, 1964, and 1965 led to the release of the variety Baladi in the 1967–68 season.

Single plant selections for high pod number were made from Baladi and Rebaya 40 in 1962–63. Continuous selection and yield testing led to the identification of the strain BF 2/2, which showed a 47.7% increase in yield over the Baladi parent. The variety was released for commercial production in the 1969–70 season.

Further yield tests over a range of locations in northern Sudan have produced the strain

Rebaya 29, which outyielded BF 2/2 as well as being stable over the range of environments. Rebaya 29 was released in the 1973–74 season.

In the 1972–73 season, a large-scale cooperative program between the Agricultural Research Corporation and ALAD provided the breeding efforts with thousands of varieties and segregating populations. Most of these were either susceptible to powdery mildew or mosaic virus, or flowered too late to give reasonable yields, but 53 promising lines were screened and adapted from this collection. Of these, a number of lines were found to outyield BF 2/2 and Hudeiba 72 by between 35 and 52% in trials during the 1975–76 season. Further yield testing has narrowed this down to 13 lines, which are entered in plot variety trials this season.

Varietal Crosses

Crosses were made with the aim of combining good agronomic characters, such as high pod set percentage, high pod number per plant, good seed size, and tolerance or resistance to powdery mildew, from different parents into selected genotypes.

Single crosses involving 10 varieties were made in the 1969–70 season and selections made in the F2, F3, and F5 generations. Pilot yield trials have shown that the yields of all selections were greater than, or equal to, the controls used. Further yield trials are now under way on this material. In addition, the most promising crosses have also been crossed with Hudeiba 72 and some promising F2 material has been obtained. Breeding work has also involved the crossing of five varieties in a 5 x 5 dialled cross, and the subsequent growing out of all seed in isolation, while encouraging intermating and crossing in an attempt to break linked characters. The highest yielding 10 selections from this program have been included in further yield assessment trials.

Specific Programs

Correlation studies have shown broad bean yield to be highly dependent on the number of pods per plant or per unit area. As a result, selections for high numbers of pods per plant have been made from all varietal crosses, screening nurseries, and irradiated material. Selection for autofertility is currently being carried out in these lines.

Breeding for resistance or tolerance to powdery mildew is considered to be of major importance in view of the damage caused by this disease. Selection for tolerance was made in local selections from Baladi and Rebaya 40 in 1962–63, from the varietal crosses made in 1970–71, from the three-way crosses made in 1975–76, from the new set of single crosses made between ALAD introductions and promising local varieties, and from X-ray irradiated material of three local types. In addition, sources of resistance were introduced from Germany and Russia and have been included in a backcross program. Although results of all these selections and testings are not yet available, as a consequence of the relative failure of disease development in the country over the past 2 years, progress looks promising.

Haricot Bean (*Phaseolus vulgaris*)

The haricot bean, or dry bean, is one of the main cash crops of farmers in the Northern Province of Sudan, especially in the area around Shendi and Berber, which grows over 97% of the small dry white bean acreage of this province and where yields are of the order of 0.6 tons/feddan.

Agronomic Aspects

The optimum sowing date for dry beans is during the last 2 weeks of October, and early sowing will again result in yield reduction, this time from plant injury due to sodium toxicity. It has been shown that seed yield is highly positively correlated with decreasing plant spacings, a spacing of 60 × 20 cm giving the highest yield. Investigations on fertilization have revealed that applications of nitrogen at sowing give significantly increased yields, but that phosphate fertilizers have little or no effect. Nodulation was appreciably improved and the nitrogen content of plants increased by inoculation with a local strain of *Rhizobium*. Short watering intervals of about 7 days result in substantially higher yields than either 14- or 21-day intervals, and this appears to be due to both a reduction of soil temperature and to the fact that sodium ions are kept at low concentrations, thus preventing damage to the crop, which is widespread when concentrations build up.

Varietal Improvement

Selection work was initiated at Hudeiba in the 1962–63 season in an endeavour to discover a more suitable variety than the long-established white and medium Baladi type. Work also commenced on breeding for tolerance to a blastlike disorder observed during the active pod-filling phase of plant growth. Few selections matched the performance of the Baladi variety and it became clear that improvements in yield and seed quality could be best achieved in this crop by selection from the standard Baladi type. The strain R0/2/1, developed from selections from the original Baladi parent, was found to consistently outyield Baladi in trials in the 1966–67 and 1967–68 seasons, and in 1969 it was released to farmers. Since then it has remained the standard variety of dry bean in the Northern Province. In 1969–70, breeding work was initiated to develop resistance and tolerance to curly top virus disease, which is transmitted by the white fly and can cause serious yield losses. Single plant selections with desirable characters for resistance to this disease were made from Baladi, R0/2/1, and some introduced varieties. Slow progress is being made in this work. To select for plants tolerant to the blastlike disorder, which has been discovered to be mainly due to sodium toxicity, the whole collection of breeding material was subjected to a variety of sowing dates and hence to a variety of exposures to sodium toxicity. This procedure will continue for a number of years and hopefully produce some degree of tolerance.

Chick-pea (*Cicer arietinum* L.)

The cultivation of chick-pea in Sudan is confined to the northern provinces, where about 12 000 feddans are grown annually and where yields are generally very low due to the insufficiency of basic agronomic information in the farming community.

Agronomic Aspects

Sowing date trials have shown that all plants sown in September and early October died within 1 month of sowing. The highest yields appear to be obtained from mid- to late November plantings, and sowing 2 weeks earlier or later than this optimum time results in considerable yield reductions. The density of planting also has an appreciable effect on seed yield, and planting on both sides of a 70-cm ridge with an interplant spacing of 5 cm has been shown to give the highest yields. The optimum recommended between- and within-row spacings for production under irrigation are 60 cm and 5 cm with one plant per hole (or 10 cm with two plants per hole). Application of 36 kg N/feddan at sowing increased yield significantly, and splitting this dressing between sowing and flowering gave even greater yield benefits. However, no response has been reported to either phosphate or potash fertilization. The high response to nitrogen application suggests that the soils have a low N status and/or rhizobial activity is poor. Inspection of plant roots revealed no nodulation and this has led to the introduction of two rhizobial strains from ICRISAT, which, although final results are not yet available, have produced very good nodulation in trials so far. Investigations into watering intervals have shown no differences in seed yield between 7-day and 21-day irrigation cycles, demonstrating that chick-pea has a reasonable level of drought tolerance.

Varietal Improvement

Chick-pea breeding work began in the 1972–73 season in cooperation with ICRISAT and ALAD, who supplied a large number of germ-plasm entries, segregating populations, disease-screening nurseries, and yield trials. The main aim of this effort is to produce varieties that combine a superior yielding ability with adaptation to a wide range of sowing dates, tolerance to sodium toxicity, and resistance or tolerance to diseases, especially wilt and stunt virus. At the same time the work emphasizes the evolution of varieties that can be fitted into improved cropping patterns.

Of the material collected from both within and outside the country, about 100 white seeded varieties were selected and grown in a large pilot trial in 1976–77. Twelve entries, outyielding the local variety Baladi by about 20%, have been entered into a standard variety trial this season and the results are being awaited.

Lentil (*Lens culinaris*)

In response to the high prevailing prices, small areas (not exceeding 200 feddans) of lentils are grown annually in the Dongola and Halfa vicinity, but crop failure is very frequent, as the climate tends to be too hot. Lack of suitable high-yielding, heat-tolerant genotypes and appropriate agronomic practices prevent the better performance of lentils in this area. However, lentil is the second-most important grain legume foodstuff in Sudan, and as a result every year the government has to import about U.S. $1 million worth of lentils to fill the gap between domestic production and consumption. To boost production and thereby replace imports, an improvement project was started at the Hudeiba Research Station in 1972.

Agronomic Aspects

In general the optimum sowing date for lentils is well defined in the last week of November, deviations resulting in dramatic yield reductions. However, highly significant interactions have been found between sowing date and soil type as affecting seed yield, the highest yields being obtained from plantings around early to mid-November on the lighter soils, and in mid- to late November for the heavier types (Table 3). Although yield increases with seed rate up to 100 kg/feddan, diminishing returns from the higher rates make the optimum rate around 60 kg/feddan. Drought stress is a very important consideration in lentil production in the Sudan, and investigations have shown that increasing the watering interval from the optimum of 7 days produced appreciable yield reductions. Neither nitrogen, phosphate, nor potash applications had any effect on seed yield, and studies have shown that this is probably due to the excessively high levels of soil salinity under which the crops are grown. Soil salinity and sodicity (excess salt in the soil ion-exchange complex) are major problems of crop production in northern Sudan. Lentils may be particularly badly affected by these conditions and studies are currently under way to investigate the levels and mechanisms of salt tolerance within the crop.

TABLE 3. Effect of sowing dates and different soil types on seed yield (kg/feddan) of lentils in the Sudan.[a]

	Soil type		
Sowing date	Sandy clay lean	Lean clay	Heavy clay
8 Oct.	4.6	5.9	13.4
22 Oct.	466.8	134.8	42.4
5 Nov.	671.0	671.0	353.4
19 Nov.	650.8	702.1	640.8
3 Dec.	331.9	81.1	308.8
17 Dec.	163.4	31.1	91.2
36 Dec.	18.1	0.8	2.1
14 Jan.	1.3	0	0

[a] Source: Annual Report, Hudeiba Research Station, Ed-Damer, Sudan.

Varietal Improvement

Breeding activities in lentils were initiated in 1973 at the Hudeiba Station. Since then they have mainly focused on the screening of both domestic and imported genetic stocks, on the basis of yielding ability and agronomic traits to provide a base for future breeding programs. Cooperative programs were established with ALAD in 1973 and latterly with ICARDA in 1977 and these supply all the genetic stocks and materials for the breeding work.

The Future Scope for Legume Crops

For the last 10 years, about 46 000 feddans of land have been devoted to legume production in the Northern and Nile provinces of the Sudan. To satisfy the projected growth in domestic consumption, and hence demand, for these commodities, considerable increases in production must be achieved over the next 10 years. This can be accomplished through an expansion in cultivated area to approximately 120 000 feddans or a similarly large increase in average yields of the existing area under cultivation. Obviously, any reasonable expansion must involve a combination of these two aspects; increasing the acreage in the northern provinces and initiating production on an increasing scale in those areas such as the White Nile and Kassala provinces, which are not traditional foci of legume production, while at the same time developing varieties that will give improved yields under the production conditions of the areas in question.

Special emphasis should be given to crops such as lentils, for import replacement, and dry white beans, the production of which has dropped appreciably in recent years as a result of marketing problems, as well as the more traditionally important and widely grown broad bean.

With the research programs geared to the evolution of high-yielding varieties with a good response to irrigation and other agronomic factors, including population density, sowing date, and fertilizer application with rhizobial inoculation, and with the potential for expansion as a substitute for cotton in the White Nile provinces schemes, the future for legume crops in the Sudan looks bright. Of course there are problems, but the continuing expansion in the scope and the emphasis of both the breeding and agronomic components of research is reducing these problems to a manageable size.

Food Legume Improvement in Tunisia

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Agriculture is considered to be the main source of the national economy of Tunisia. Most of the cultivated land is restricted to the north of the country and farming is almost entirely under rainfed conditions. In this region, with mild winters and hot summers, the annual rainfall varies from 400 to 800 mm. The bulk of this precipitation normally occurs in the late fall, winter, and early spring, but its amount, intensity, and distribution fluctuates widely between years. This interseasonal variability is a feature of most of the climatic factors within the Tunisian environment. Great variations in the total rainfall, the onset of the growing season and its duration, the rainfall distribution during the season, the occurrence of frost and hail, and the timing of stress periods make predictions based on seasonal averages of environmental conditions very misleading and dangerous. Data derived and observations made in any one season must thus be considered against this background of variability when making predictions concerning the future.

The soils in northern Tunisia are very variable: black and grey–brown rendzinas are common, but good deep soils of alluvial origin are also found throughout the region.

Grain legumes are generally only grown in areas with an annual rainfall greater than 350 mm and on average occupy 100 000 ha of land, which is 6% of the cereal production area. The annual acreage of grain legumes, however, varies considerably (see Table 1), being dependent on the amount and distribution of the rainfall over the whole season. Average yields of grain legume crops are low, about 800 kg/ha for broad beans, 650 kg/ha for lentils, 600 kg/ha for dry peas, and 850 kg/ha for chick-peas (Table 1), and could easily be doubled or tripled with adequate fertilization and other practices. However, farmers are wary of using fertilizers, as previous experience has given very poor returns, probably due to the use of varieties with low yield potentials, late maturity, and disease susceptibility.

Utilization and Marketing

Most of the grain legumes are consumed as dry seed by the population, although a small amount is also used for animal feed. Although Tunisia exports approximately 11 000 tonnes of broad beans and 4600 tonnes of chick-peas per year, the substantial difference between production and domestic consumption of dry beans and peas necessitates the annual importation of about 2600 and 1350 tonnes of these crops, respectively.

Although the average price of grain legumes has increased rapidly over the past 2 years as a result of lower average yields, the prices paid to farmers remain very unstable due to low quality and irregular production. This instability results from factors that include the variable climate, the poor varieties, and the losses from disease and pest attacks, which cause low and variable yields; and the lack of on-farm storage facilities, which means that the farmers must sell their produce soon after harvest in a glutted market and at a consequently low price.

TABLE 1. Area (ha), production (metric tonnes), and average yield (kg/ha) of dry legumes in Tunisia for the period 1971–77.

	Broad beans			Lentils			Dry peas			Dry beans			Chick-peas		
Year	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1971	37507	22504	600	4567	2284	500	6947	3474	500	–	–	–	25000	17500	700
1972	30000	18000	600	7000	3000	430	8000	4800	600	–	–	–	30000	21000	700
1973	–	37000	–	–	4000	–	–	5000	–	–	–	–	–	19000	–
1974	53571	43515	812	5085	4248	840	5634	4383	780	–	–	–	19940	17620	880
1975	57847	54105	940	3372	3562	1060	5351	4605	860	–	–	–	20565	18387	900
1976	61177	66476	1090	628	436	700	5416	4296	790	–	–	–	19799	19148	970
1977	58500	24170	423	1400	730	520	7800	2950	380	2200	2180	990	21700	16900	780

Production Practices

Cultivation generally follows a 2- or 3-year rotation scheme, the 2-year system involving a legume followed by a cereal, and the 3-year rotation a forage–legume–wheat pattern. Both rotations are common throughout the arable areas and give good control over weeds in the cereal crops. However, the three-course system is the most economic and farmers are increasingly favouring it over the more simple traditional two-course rotation.

Grain legumes are always grown as rainfed crops. Broad beans are planted from mid-October to late November and harvested from late May onward; lentils and peas are planted during the period mid-November to late December and harvested in mid- to late June; and chick-peas and dry beans have the shortest growing season from planting in early March to mid-April to harvesting from the end of July. Production practices are mechanized in some regions of the country, but in many areas sowing, weed control, and harvesting are all carried out by hand. Although still well below the optimum, fertilizer use on legumes in Tunisia has been steadily increasing in recent years. Currently, phosphate is the only fertilizer routinely applied (at between 130 and 180 kg/ha), as the soils do not lack potash, and nitrogen is not normally required by legume crops especially under conditions of reasonable soil fertility. Together with moisture stress, weeds are perhaps the most important constraint to pulse production in Tunisia, and the elimination of these competitors will do much to increase yields and hence total production in the country. Herbicides have been used for weed control for several years, but usage has been confined to only 10% of the legume area, while over 50% is still hand weeded. At present, Treflan is used to control grass weeds, and other compounds such as Gesatop 50 for dicotyledons, but much work still needs to be done on the phytotoxicity of such chemicals to the current or succeeding crops in the rotation, to prevent adverse effects from their more widespread usage.

Insects

The two most important insect pests are the larvae of *Hypera crinita* (leaf weevils), which are very common in broad beans, and aphids, which affect all the pulse crops to a varying degree depending upon climatic conditions during the growing season, higher temperatures tending to result in earlier and heavier infestations and hence more crop damage. At present, control of *Hypera* is achieved through spraying with Phosaline (Azophene), and of aphids by Primor and Dimethoate.

Diseases

The main disease problems on legume crops include chocolate spot (*Botrytis* sp.), blight (*Ascochyta* sp.), wilt (*Fusarium* sp.), and rust (*Uromyces* sp.). Crop losses vary with climatic conditions and may be considerable in some seasons. Benomyl (Benlate) is currently used to control infections of *Botrytis*, whereas the other diseases are usually minimized through the modification of cultural techniques.

Other Pests

Orobanche, the parasitic broomrape, can be a problem in some areas and, although there are no sharply defined control measures, infestations may be minimized by cultural and rotational techniques.

Most grain legume varieties grown in Tunisia are local cultivars traditionally adapted to survive the unfavourable growing conditions characteristic of rainfed culture in the dry lands. However, these varieties have low yield potentials and very little resistance to pests and diseases and, as a result, regularly produce low and very variable yields. The identification and introduction of improved grain legume varieties with disease and pest resistance and adaptability, combined with high yield potential, stability, and adequate grain quality are thus essential prerequisites to the expansion of legume production in Tunisia. Lack of sufficient mechanization in these crops is a further problem, and considerable work remains to be done in this field to popularize the pulse crops with the farming community.

Research Activities

Legume research and extension work is mainly carried out by the Technical Division of the Office of Cereals (ex-Wheat Project) in cooperation with the National Agronomic Institute of Tunisia (INAT) and the National Agronomic Research Institute of Tunisia (INRAT).

Research is predominantly geared to the development and introduction of high-yielding varieties and the screening of varieties for disease and lodging resistance, drought tolerance, and adequate grain quality; the improvement of local varieties through selection and crossing with high-yielding cultivars; and the optimization of cultural practices, including fertilizer applications (especially phosphorus), rates and dates of sowing, weed and insect control measures, tillage practices, and rotational systems. The varietal testing work involves a number of different nurseries of broad beans and chick-peas grown at two locations, namely Bourbia, with an annual precipitation of 320–400 mm, and Mateur, where the rainfall is between 500 and 600 mm per year.

Extension work, on the other hand, involves encouraging the farming community to adopt improved technologies and practices through information dissemination by the mass media; conducting farmer's field demonstrations; organizing meetings and field days to illustrate the results of good technical practices; and helping to ensure the availability and timely distribution of adequate supplies of seed, fertilizer, and herbicides to the farmers.

However, both research and extension activities are severely hampered by the scarcity of physical resources and trained manpower. As a result, the food legume crops, which are so important in terms of their contributions to the protein nutrition of the population and to soil fertility, have been seriously neglected in terms of practical research related to varietal and cultural improvement. It is becoming increasingly urgent that we focus much more research attention and expertise on improving the two major legume crops of specific importance to the country, namely broad beans and chick-peas, to allow the expansion of production justified by their contributions to both agriculture and nutrition. This can only be done by establishing increasing linkages and cooperative activities with other national and international research efforts working in the region, especially in the fields of training and information exchange, as well as the more widely used facilities of the regional nursery program. At the same time, it is vital that increasing linkages be established between the research and the extension activities of the national improvement efforts, so that the new technologies and practices developed by research, together with cooperating research programs, can be translated into the real improvements in production that result from farmers actually implementing these innovations in the correct way.

Food Legume Production and Improvement in Lebanon

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Lebanon, with a total land area of only 10 500 km^2, is the smallest country in the eastern Mediterranean region. It is characterized by an extreme variability in environmental conditions. The terrain changes, as one moves inland, from flat coastal plains, through mountain ranges, to the high altitude Beka'a Valley; the average annual rainfall varies from 250 mm in the inland areas to 1400 mm in the mountains, which may be under snow for 3–4 months of the year; and temperatures range from −8 °C in the winter to 36 °C in the summer months.

Due to the reasonably high summer temperatures and long growing period, coupled with the availability of irrigation water in the drier regions, the role of food legume crops in the agricultural sector of the economy is relatively minor in comparison with other more intensive and high-return fruit and vegetable crops. The average annual production of legume crops in Lebanon between 1963 and 1973 is shown in Table 1.

The rather low yields of legume crops throughout the country reflect the lack of importance attached to these crops by the farming community, and possibly also the lesser overall importance of agriculture in the national economy. Grain legumes are normally grown in a 3-year rotation with cereals and summer vegetables and are almost invariably produced using traditional means. Lentils, chick-peas, and broad beans are usually broadcast, often into shallow furrows that are then covered with a cultivator and appear almost as row-planted crops. Lentils are sown in November and December at a rate of about 200 kg/ha, whereas chick-peas and broad beans are both sown at 150 kg/ha, the former as a spring crop in March and the latter as a winter crop in November. Planting dates vary somewhat with location, and in general are earlier in the lowland coastal plains than in the higher elevations of the Beka'a. Fertilizers are seldom applied to the crop. Although hand harvesting is still practiced throughout the country, most threshing involves the use of cereal threshers.

The lack of mechanization for planting and harvesting is a major production constraint, especially in view of the increasing cost and scarcity of hand labour at these times. Diseases, such as *Ascochyta* blight, *Alternaria* spot, rust (*Uromyces* spp.), and chocolate spot (*Botrytis cinerea*), frequently become severe, causing considerable crop losses. In addition, lentils are infested with weevils, chick-peas with caterpillars, and broad beans are very prone to aphid damage. The lack of improved varieties with resistance

TABLE 1. Area (ha), production (metric tonnes), and yield (t/ha) of legume crops in Lebanon, 1963–73.

Crop	Area	Prod.	Yield
Dry beans	908	861	0.9
Broad beans	572	667	1.2
Lentils	3067	1232	0.4
Chick-peas	2769	1866	0.7
Dry peas	161	142	0.9

or tolerance to these diseases and pests, and the poor general standard of agronomic practices used for legume cultivation in lebanon, coupled with the problems resulting from its labour intensiveness are making legume production increasingly less economic, especially when compared with alternative crops such as cereals, fruits, and vegetables, which give more stable yields and higher returns.

Both the Agricultural Research Institute and the Faculty of Agriculture at the American University of Beirut are actively involved in agricultural research, which includes work on the legume crops. Studies on nutritional quality, agronomy, nitrogen fixation, and breeding and selection are carried out by these institutes and results have been published and used both locally and internationally. In recent years research work involving food legume crops has been given a considerable boost by assistance provided by international organizations such as ALAD (now ICARDA), FAO, and IDRC. The food legume component of the ALAD regional project initiated in Lebanon in the early 1970s has stimulated an increased expansion of research activities, and its continuation and elaboration in the recently formed ICARDA is seen as a great advantage for future work in this field. Unfortunately, the recent and continuing civil disturbances throughout the country are at present making the planning and implementation of research work very difficult.

Grain Legume Production in Turkey

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Turkey forms a bridge between Europe and Asia, and is bounded by sea on three sides. It covers 779 452 km^2 and can be divided into nine distinct agroecological zones (Fig. 1). The climate varies considerably across the country; extremes of summer heat and winter cold, and a meagre 250–300 mm annual rainfall are experienced in the interior areas and in East and Southeast Anatolia; and the coastal areas, by virtue of the maritime influence, have a milder, less extreme climate with between 550 and 1000 mm of rainfall per annum. The soils also exhibit appreciable variation, but are, in general, rich in lime and potash and deficient in available phosphate and nitrogen.

Grain legume crops occupy about 461 000 ha or approximately 2.8% of the total g from its labou Lentils are the most widely grown of these crops, followed by chick-peas, *Phaseolus* (dry) beans, broad beans, dry peas, and cowpeas. The changes in area, production, and yield of these pulses in Turkey between 1960 and 1976 are illustrated in Table 1. Lentils, chick-peas, and dry beans are grown throughout the country, with the possible exception of the very mountainous East Anatolian area. The cultivation of dry peas and broad beans, however, is confined to the milder coastal regions, and cowpeas are grown solely in West Anatolia. Yields vary between regions depending on environmental conditions, but these differences are not significant.

Utilization and Marketing

In Turkey, food legumes are used almost exclusively for human consumption, chick-peas and lentils mainly being eaten as the dry seed, and broad beans, peas, *Phaseolus* beans, and cowpeas eaten as green pods, green seeds, or dry seeds. The green seeds of

Fig. 1. Main agroecological regions of Turkey.

TABLE 1. Area (ha), production (metric tonnes), and yield (kg/ha) of grain legumes in Turkey, 1960–76.

	Chick-pea			Lentil			Dry peas			Dry beans			Broad beans			Cowpeas		
Year	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1960	86500	97000	1121	104000	98000	942	2000	2400	1200	115000	150000	1304	39000	51000	1308	2000	2000	1000
1965	85000	89000	1047	100000	90000	900	5000	6000	1200	110000	140000	1273	35000	45000	1286	2400	3000	833
1970	100000	109000	1090	108000	92000	852	3700	4000	1051	99000	138000	1394	29000	39000	1345	2500	2300	920
1971	110000	133000	1209	105000	101000	962	3000	4200	1400	102000	153000	1500	31000	42000	1355	2250	2050	911
1972	161902	182964	1130	103209	105400	1021	3160	4538	1436	104511	158465	1516	32735	46736	1428	2150	2100	977
1973	184092	185271	1006	85044	67204	790	3000	4400	1467	99498	147000	1477	31000	45998	1484	2100	1900	905
1974	175050	195000	1114	115960	120000	1035	2500	3490	1396	100000	144000	1440	34000	54000	1588	2000	1800	900
1975	139991	171900	1228	124428	135000	1085	2750	3500	1273	94001	155000	1649	30950	49920	1613	2000	2500	1250
1976	137960	170003	1232	186000	210040	1129	2900	4000	1379	102001	158375	1553	29994	47500	1584	1949	1850	949

these latter crops are also used in the canned food industry. The by-products of legume seed production are used extensively as animal feeds and fetch much higher prices than the by-products of cereal crops.

Turkey annually exports considerable quantities of chick-peas and lentils and smaller amounts of *Phaseolus* beans, broad beans, and cowpeas, but no dry peas. In the past 4 years the quantities of chick-peas and lentils exported have risen dramatically and these crops now make an appreciable contribution to the agricultural foreign earnings of the country.

Production Practices

Lentils and chick-peas are commonly grown in a 2-year rotation with winter cereals, especially wheat. The other pulses can be grown in several alternative systems involving cereals and industrial crops, such as cotton and sugar beet.

Lentils can be grown as a winter or summer crop, being sown in November and February for harvest in mid-May in the southeast, and in October–November and February–March for harvest in May–June in the central areas. Broad beans and peas, predominantly cultivated in the Mediterranean and Aegean coastal regions, are sown as winter crops in November for early green seed and as summer crops in February–March for dry seed production in July. In contrast to the other crops, chick-peas, *Phaseolus* beans, and cowpeas are only produced as spring-sown crops. Chick-peas are sown in an extended season from March to May and harvested, depending upon sowing date, between June and mid-August. The planting of *Phaseolus* beans and cowpeas is governed by the occurrence of the last frost of the season, and usually takes place at the end of March in south and west regions, mid-April in central regions, and later still in the east of the country. Harvesting is carried out during the month of August.

With the exception of lentils, no improved varieties of grain legumes are currently being grown by the farming community. However, four winter and two summer varieties of lentils stemming from the breeding work at the University of Ankara and the Agricultural Research Institute at Eskisehir are now available. More emphasis is placed on the winter crop as yields can be 100% greater than with summer production.

Seedbed preparation is carried out with a heavy plough, duckfoot plough, or sweep plough, the latter of which has become increasingly favoured in recent years. The seed is usually broadcast, but row sowing is now gaining in importance. Seed rates are calculated according to the seed size and the field spacing, which is 15–20 cm between rows and 2–3 cm within rows in the case of lentils, 20–30 cm between rows, and 10–15 cm within rows for chick-peas, broad beans, *Phaseolus* beans, and cowpeas, and 30–40 cm between rows for dry peas. None of the seed is inoculated with *Rhizobium* bacteria before sowing.

Until recently, fertilization of legume crops was nonexistent, but most pulse crops now receive about 40 kg/ha of nitrogen and 60 kg/ha of phosphate at sowing. Besides chick-pea and lentil, which are traditionally grown under rainfed conditions, broad beans and dry peas are also cultivated without recourse to irrigation in Turkey. This is because the coastal areas in which they are predominantly grown receive high rates of rainfall. However, *Phaseolus* beans and cowpeas may receive furrow or flood irrigation in the drier areas when conditions dictate.

All the pulse crops are harvested by hand, although in some areas lentils are now being reaped with the aid of a grass cutter. After harvesting they are field dried and then threshed on a hard piece of ground before the seed is finally separated from the chaff by winnowing. Lentils are also threshed using wheat threshers in some parts of the country.

Pests and Diseases

Seed beetles (*Bruchus* sp.) cause considerable seed losses in all the pulses with the exception of chick-peas, where *Liriomyza congesta* (the chick-pea fly), may be very damaging. A large amount of damage is also caused by various soil-living pests, such as the army worm (*Laphygma exigua*) and the cutworms (*Agrotis* sp.). The control of these insects can be achieved through the treatment of the soil with suitable chemicals or seed treatment with insecticides such as Ceresan. Bruchids are controlled by fumigating the threshed seed with phostoksin before storage.

Both fungal and viral pathogens are fairly widespread in the country, affecting all the legume crops. Root rot caused by *Fusarium oxysporum* and *Pythium ultirnum* has become a major problem in all the pulses, especially in chick-peas, where together with *Ascochyta* blight (*A. rabiei*) it causes the bulk of crop disease losses.

Weeds are removed manually in one or two operations during the season; herbicides are not used for weed control as yet.

There is currently a great opportunity for considerable increases in the production of the major grain legume crops in Turkey, especially in view of the buoyant export market for grain legume products. However, at present, expansion is hindered by several major yield-limiting factors. These include disease problems, costly and inefficient manual weed control and harvesting practices, and high overall production costs, which, together with variable yields, make the legume crops poor competitors with the proven profitable crops such as wheat. With the elimination of these important constraints, the chances of real increases in the production of pulses, especially lentils and chick-peas, are high, as these crops can be cultivated on land otherwise kept fallow and hence not affect the production of the other major crops. This effect can be illustrated by the 86 000-ha increase in the area under lentil cultivation that has taken place over the past 4 years as a result of the introduction and use of winter-hardy varieties.

Research Activities

The Department of Plant Growing and Breeding in the Faculty of Agriculture of the University of Ankara has pioneered research on food legume crops. In the past 4 years, however, various other agricultural faculties, together with some agricultural research institutes supported by the Ministry of Agriculture, have also initiated work on these crops. The results and improvements generated by this research are extended to the farming community through the Ministry of Agriculture. Seeds, fertilizers, and machinery are also made available through this channel.

Research priorities in grain legumes emphasize the evolution of varieties of lentils, chick-peas, broad beans, and dry peas that are resistant to cold, drought, diseases, and pests, and suitable for mechanization, and that have desirable seed characteristics (white and large-seeded chick-peas are preferred by consumers).

Research to date has virtually ignored broad beans and dry peas in favour of a concentration on the more popular lentil and chick-pea crops. Four improved winter varieties and two improved summer varieties have already been registered as a result of breeding work in lentils, and this and other work on the effect of plant spacing on growth and yield characteristics is continuing. Investigations on yield determinants, and the effect of plant spacing and sowing dates on crop development, are also underway in the chick-pea program. Studies of heritability percentages and the incorporation of *Ascochyta* blight resistance into local varieties have been the main emphases of chick-pea breeding work. There is an obvious need to expand both the breeding and agronomy work in Turkey so that the high potential of the legume crops in the agriculture of the country can be more fully realized in the near future.

Food Legume Research and Production in Cyprus

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The island of Cyprus is situated in the eastern Mediterranean and has a semi-arid climate. In the coastal plains, rainfall varies with location and ranges between 200 and 500 mm per annum, of which the bulk falls during the period November to May leaving the summers almost completely dry. The winters are mild with monthly minimum (night) temperatures around 5–7 °C and maximum (day) temperatures 15–20 °C, and the summers hot with mean monthly maximum temperatures reaching 35–38 °C. The inland plains are characterized by lower rainfall and wider differences between day and night temperatures than the coastal plains, where the influence of the Mediterranean produces a wetter less variable climate with warmer winters and a lower incidence of frost. It is thus in these coastal regions that food legume crops perform particularly well, although they are also cultivated on a small scale during the summer months on the mountains of Troodos (central to western Cyprus), where rainfall may reach 1200 mm per annum.

Legume Production and Utilization

The distribution of the major food legume-growing areas across the country is illustrated in Fig. 1, and the area and production levels of the various different legume crops for the years 1960 and 1975 are shown in Table 1.

Chick-peas and lentils are produced under rainfed conditions, haricot beans are entirely irrigated, and the other pulses produced in Cyprus, which include broad beans, cowpeas, field peas, and "*louvana*" may or may not be grown under irrigation, depending on the seasonal availability of water.

Broad Beans (*Vicia faba*)

Broad beans are consumed locally as dry seeds, green seeds, and green pods. Green seeds are eaten fresh during season and preserved by canning or freezing outside season. By-products of seed production, which include the stubble and the pods from green seed, are utilized for animal feed.

The crop is commonly grown in rotation with cereals or vegetables, such as potato, the local large seeded variety being exclusively used. Almost any type of soil is suitable for broad bean cultivation, and the crop growth period is 3–5 months when harvested green, or 5–6 months when used for dry seed production. Planting usually takes place during the period December to February, although small areas may be sown in September–October to supply the early market for green pods in December. Such areas are confined to the coastal lands, as a low incidence of frost is necessary for this early season production. For the more normal production pattern, the land is cultivated once or twice prior to sowing for weed control, fertilizer, or manure incorporation and seedbed preparation. Fertile soils receive no additional fertilization, although up to 100 kg/ha of phosphorus and 30 kg/ha of nitrogen and potassium may be used on the poorer lands if soil analysis shows a deficiency. The seed is either broadcast or sown in rows 30, 45, or 60 cm apart, and seed rates range from 150 to 200 kg/ha, the lower seed rates and wider spacing being preferred on the more

Fig. 1. Areas where food legumes are grown in Cyprus.

TABLE 1. Area (ha), production (metric tonnes), yield (kg/ha), and consumption (tonnes) of the major pulses in Cyprus, 1960 and 1975.

	Area		Production		Yield		Consumption[a]	
Crop	1960	1975	1960	1975	1960	1975	1960	1975
Broad bean	2943	1338	1611	1524	548	1139	1838	1162
Phaseolus bean	1605	803	1745	813	1087	1013	1699	1659
Chick-pea	683	535	305	305	447	570	830	448
Lentil	1204	268	448	203	372	758	482	380[b]
Cowpea	1338	937	339	406	253	433	847	509

[a] Consumption = production + imports − exports.
[b] 1974 figure.

fertile lands. In all cases, sowing is by hand and a mouldboard plough is used to cover seed sown in 30-cm rows, although this operation is carried out with a ridger plough for the wider spacings.

Postplanting weed control usually involves spraying with Gramoxone upon the emergence of the first few seedlings, followed by hand hoeing later in the season, when the plants are about 15–20 cm high. A selective herbicide has been used effectively recently to replace these measures, but at present it is still under test and has not been released for widespread use.

Traditionally all harvesting is carried out by hand, dry seeds being threshed from the plant debris on a threshing floor by means of a special piece of wood or a tractor rolling over them, and then winnowed. Last year, however, a specially modified combine harvester was used to successfully harvest large areas of broad beans in the west of the country.

Production is limited by a number of pests and diseases, the most important of these being insect pests, including aphids (*Aphis rumicis* L.), weevils (*Sitona lineata*), and seed beetles (*Bruchus rufimanus*), and fungal diseases such as chocolate spot (*Botrytis fabae*), rust (*Uromyces fabae*), and *Fusarium* spp.

Haricot Beans (*Phaseolus vulgaris*)

These beans are also consumed as green pods, which may be preserved by freezing, and dry seed, preserved for export in cans, as baked beans.

Improved varieties such as Harvester, Bush Blue Lake, and Stringless Blue Lake are grown for green pod production, whereas the local variety Morphitico is used for dry seed production. Haricot beans are grown on a wide range of soil types. After an initial deep cultivation, the fields are flood irrigated and the seedbed prepared. The beans are then sown into the moist soil and not irrigated until after emergence. Seed rates depend on the variety and range from 65 to 85 kg/ha for bush types to 30–50 kg/ha for climbing varieties. No fertilizer is applied to soils of high fertility, but 150 kg/ha of phosphorus and 30 kg/ha of nitrogen and potassium as required are used on the poorer soils.

Green pod production only takes place in small areas, and sowing, which is in rows, weeding (hoeing), and harvesting are all carried out by hand. The growing period usually extends from March to October, but some crops are also produced during the cold winter months in green houses. Both bush and climbing varieties are used for green pod production; however, cultivation under glass normally involves the climbing variety, Stringless Blue Lake.

There are two main crops of haricot beans for dry seed production: the spring crop, sown from the end of March to the beginning of April; and the autumn crop usually sown in August. In both cases, the seed is normally broadcast by hand and harrowed into the moist soil. Weed control is achieved mainly by presowing cultivations in the spring crop, which only requires limited irrigation, whereas the autumn crop, which needs four to five flood irrigations during its 3–4 month growing period, requires hand hoeing for adequate control of weeds. Production costs for the autumn crop are thus much higher than for the spring one, but this is offset by the higher yields and larger seed obtained from the autumn crop. Both crops are harvested just before the pods dry completely, the plants being pulled out by hand, heaped, and left to dry in the field and then threshed with stationary threshers.

The main disease problems of economic importance are rust (*Uromyces appenticulatus*), *Sclerotinia sclerotiorum*, *Fusarium solani*, and tobacco mosaic virus (TMV), and the major pests include aphids (*Aphis* spp.), weevils (*Sitona lineata*), bean fly (*Agromyza phaseoli*), and spider mite (*Tetranychus telarius*).

Chick-peas (*Cicer arietinum*)

Chick-peas are consumed almost entirely as dry seed, either preserved in cans as hommos, mainly for export, or roasted as a snack. The dry stubble is used extensively for livestock feed and forms a very valuable by-product.

As with broad beans and haricot beans, chick-peas are usually grown in rotation with either cereals or vegetables. Sowing takes place between January and March following several cultivations for weed control and seedbed preparation. Late sowing is preferred to ensure adequate weed control, but results in lower yields than sowing earlier in the season. The seed is normally sown, broadcast or in rows, by hand, and seed rates vary from 40 to 75 kg/ha. On the poorer soils up to 75 kg/ha of phosphorus and 20 kg/ha of nitrogen may be applied at sowing. Weed control within the crop is mainly achieved through hand hoeing; however, there is currently an increasing tendency toward greater reliance on chemical control methods. Harvesting is by hand and follows the same procedure as dry haricot bean seed production.

The main diseases are blight (*Ascochyta rabiei*) and powdery mildew (*Erysiphe polygoni*), and pests include spider mite (*Tetranychus* spp.) and pentatomid bugs (*Dolycoris baccarum*).

Cowpeas or Black-Eye Beans (*Vigna unguiculata*)

These are consumed as green pods or dry seed, the dry seed also being preserved in cans for consumption outside the season.

Cowpeas are sown in April–May on heavy soils in rotation with cereals and are expected to grow and mature on residual soil moisture resulting from the winter rains, without the need for irrigation. Only small areas are devoted to cowpea production; a local variety is used and all operations are carried out by hand. The seeds are either broadcast or row planted using seed and fertilizer rates similar to haricot beans. Weed control is by preplanting and postemergence cultivations, and the main diseases and pests are similar to those affecting haricot beans, with the addition of *Lampides baeticus*, an insect whose larvae feed on the grain in the pods.

Field Peas (*Pisum sativum*)

Peas are eaten as green or dry seed, and green pods. The green seed is preserved in cans or frozen for off-season consumption.

Only a very limited area is used for dry seed production under the direction of the Seed Production Department. Peas for green seed are sown in August for autumn–early winter harvest or in autumn for harvesting in the spring. The main variety used is Onward, and the seed is usually broadcast, although some is sown in rows, at the rate of about 80 kg/ha. Fertilizer rates vary from zero to 100 kg/ha of phosphorus and 15–20 kg/ha of nitrogen. Both weed control and harvesting are carried out by hand.

Powdery mildew (*Erysiphe polygoni*), blight (*Ascochyta pisi*), rust (*Uromyces pisi*) root rot/wilt (*Fusarium* spp.), and TMV are the major disease problems of peas. Pests such as seed beetles (*Bruchus* spp.), aphids (*Aphis* spp.), spider mites (*Tetranychus* spp.), weevils (*Sitona* spp.), and pentatomid bugs (*Dolycoris Baccarum*) may cause considerable economic damage to the crop.

Lentils (*Lens culinaris*)

The local variety is grown exclusively and on light alkaline soils, mainly in hilly areas in rotation with cereals. Sowing takes place between December and February, following the weed control and seedbed preparation cultivations. All the seed is broadcast by hand at the rate of about 50 kg/ha. Fertilizer may be applied at 40–50 kg/ha of phosphorus, with small doses of nitrogen at the time of sowing. The mature seed is harvested by hand, heaped in the field to dry, and threshed in stationary threshers.

The main diseases are *Ascochyta* blight and powdery mildew (*Erysiphe polygoni*) and the pests include *Bruchus* spp., *Aphis* spp., and *Tetranychus* spp.

Louvana (*Lathyrus ochrus*)

This crop is consumed exclusively as dry seed, is only grown on a limited area, and is not of any economic importance. A local variety is used and most operations are carried out by hand.

No seed inoculation is practiced in any of the legume crops. Tests have shown no yield responses to inoculation and it has been concluded that sufficient nitrogen-fixing bacteria already exist in the soil.

Weeds vary with location and soil type, but in general the major species and genera of importance in food legume crops are: *Gallium sefaria*, *Digitaria*, *Poa*, *Panicum*, *Malva*, *Convonvulus arvensis*, *Amarathus*, *Fumaria*, *Helychrysum*, *Alopecurus*, *Sinapis arvensis*, *Oxalis corniculata*, *Papaver rhoeas*, *Chrysanthemum segetum*, *Sonchus*, *Urtica euphobria*, and *Cynodon dactylon*. When legumes are grown in rotation with cereals, there may also be infestations of wild oats (*Avena* sp.) and ryegrass (*Lolium* sp.).

All pests and diseases are controlled through chemical and cultural methods used separately and in combination.

Two major and closely related factors, namely mechanization and weed control, at present limit food legume production in Cyprus. Lack of mechanization, especially in sowing and harvesting, make it impossible to cultivate grain legumes on large areas. The decreasing availability of labour and its rising costs are making the absence of mechanization in all production processes much more acute. As a result, legumes are only produced on very limited areas normally confined to the coastal plains where soil fertility is high.

Research Activities

Most research in Cyprus is carried out by the Agricultural Research Institute, although some work is also undertaken by the farmers themselves and other organizations such as food processing companies and seed merchants. There is no legume section, as such, in the Agricultural Research Institute, but staff from the Vegetables, Plant Protection, Soils and Water Use, and Economics sections are involved in investigations on these crops. As a result, work on food legumes has so far been rather limited. Varietal improvement has consisted solely of testing introductions of broad beans, haricot beans, peas, chick-peas, and lentils. Studies of mechanization of sowing, weed control, and harvesting have been confined to chick-peas, and to some extent broad beans, but, although only carried out on a small scale, have proved quite successful and encouraging. And investigations into production techniques and irrigation and fertilizer requirements have so far only emphasized haricot bean production. Research into plant protection methods has been, in general, wider, but much work still remains to be done on broad beans, chick-peas, and lentils.

Extension support has been traditionally provided by the Department of Agriculture, but chemical products agents are currently becoming increasingly involved in advising farmers regarding plant protection methods. The supply, distribution, and export of seeds is mainly the responsibility of the Seed Production Unit, and this organization and other groups involved in grain legume production, distribution, and marketing conduct various investigations in this overall field.

Until recently, food legumes in Cyprus were produced almost exclusively for the home market. However, despite the declining trend in home consumption (see Table 1), the increasing export demand, especially for broad beans, chick-peas, and lentils and all processed legume foods, has more than compensated for the flagging home market; and it is currently providing a very great incentive to expand grain legume production in the country. To be able to respond to these pressures for expansion it will first be necessary to pave the way by reducing or eliminating the severe constraints to increased production resulting from insufficient mechanization and inadequate and costly weed control measures, amongst other problems. This can be accomplished by a considerable expansion and strengthening of legume research capabilities and activities within the country as a whole. Such an effort is the first step toward elevating the grain legume crops to their rightfully important place in the agriculture of Cyprus. The other steps will follow from this base.

Broad Beans (*Vicia faba*) and Dry Peas (*Pisum sativum*) in Ethiopia

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Ethiopia lies entirely within the tropics between latitudes 3° and 18°N and longitudes 33° and 48°E. The climate ranges from permanently humid with hot summers to tropical semidesert and desert, and on this basis the country can be divided into four main zones:

(1) the "Quola" or hot zone, with altitudes below 1800 m and an average annual temperature greater than 20 °C; the cropping of broad beans and peas is very limited in this area due to the severe and numerous diseases;

(2) the "Weyna dega" or temperate zone, where the altitude varies from 1800 to 2400 m and average temperatures are between 16 and 20 °C; within this zone the importance of broad bean and pea cropping is considerable and increases with altitude;

(3) the "Dega" or cool zone, which has altitudes of 2400–3800 m and where average temperatures vary from 10 to 16 °C; the cropping of broad beans in this region extends up to an altitude of about 3000 m; however, above 2900 m chocolate spot (*Botrytis fabae*) and frost severely limit production;

(4) the mountain zone, with altitudes in excess of 3800 m and an alpine climate; the vegetation here is predominantly alpine and there is no cropping.

In the major broad bean and pea production area, the "Weyna dega," the bulk of the annual precipitation normally falls during the period June to mid-September. Maximum temperatures rarely exceed 27 °C, and although diurnal variations during the dry period may be as great as 22 C°, variations during the period of rainfall are usually of the order of 6 C°. At altitudes greater than 2100 m night frosts may occur between November and the end of January.

Ethiopian soils are generally of a very high clay content and vary from red to red/brown on the mountains, through red/brown on the slopes and brown to dark in the rolling country, to very dark and nearly black in the plain lands.

Broad Beans (*Vicia faba*)

Pulse crops are grown on an estimated 8% of the total Ethiopian arable area, in contrast to the cereals, which occupy over 70%.

Although broad beans are generally considered to be secondary in importance to chick-peas in the agriculture of the country, Ethiopia is one of the leading nations in the world in terms of broad bean production. Approximately 150 000 ha, or 1.5% of the total cultivated area, is annually devoted to the production of broad beans, which exceeds 140 000 metric tonnes (Table 1).

Broad beans can be found growing in every province in Ethiopia, usually in rotation with small grain cereals. The provinces of Shoa, Wello, Tigrai, Begumdir, and Gojam (Fig. 1) are the most important production areas.

Current Production Practices

Broad beans are produced almost exclusively by traditional methods. The land is prepared using traditional wooden- and steel-pointed ploughs, which break the soil but do

TABLE 1. Broad bean and dry pea production in Ethiopia 1967–77.

	Broad beans			Dry peas		
Year	Area ('000 ha)	Yield (Q/ha)	Prod. ('000 t)	Area ('000 ha)	Yield (Q/ha)	Prod. ('000 t)
1967	131.4	9.2	120.9	130.0	9.2	119.6
1968	136.0	9.3	125.9	131.8	9.2	121.6
1969	140.2	9.4	137.5	133.5	9.3	123.9
1970	144.0	9.6	137.8	135.0	9.4	126.4
1971	147.3	9.8	144.9	136.2	9.5	129.5
1972	150.0	10.2	152.9	137.1	9.7	132.4
1973	137.0	8.5	118.7	150.0	4.9	73.5
1974	138.0	8.6	294.8	151.4	4.9	74.2
1975	259.0	11.1	304.4	108.0	4.4	47.5
1976				107.0	4.8	65.1
1977				138.4	7.4	51.8

Fig. 1. Provincial divisions of Ethiopia. The provinces of Shoa, Wello, Tigrai, Begumdir, and Gojam are the most important production areas for broad beans.

not turn it; three ploughings are normal prior to broad bean planting, whereas only two are usual for pea production. Broad beans, in common with legumes in general, are frequently grown on poor and sometimes badly eroded soils where cereals are expected to fail. They may also be grown in mixtures with field peas. Planting normally takes place at the beginning of the rainy season in June and the crop is thus harvested in December or January. In some regions, however, namely Wello, and the north of Bale and Sidamo, broad beans are produced off-season during the winter months.

Trials conducted at research stations throughout Ethiopia have established that the optimum plant density for broad bean production may be obtained with a sowing rate of 150–200 kg/ha and a spacing of 5 cm between plants and 40 cm between rows. However, most farmers broadcast their seed at about 150 kg/ha and receive average returns of between 7 and 10 quintals/ha, which is well below the optimum. Applications of 100 kg/ha of phosphate are generally recommended for broad beans.

The crop is normally harvested when most of the leaves have dropped, most of the pods have turned black, and the upper pods are yellowing. The harvesting date varies with altitude but may start as early as late October. Once the crop is cut, it is stacked and left in the field to dry for about 6 weeks before being threshed, using animals (oxen or horses) that trample the crops spread out on a hard piece of ground. Wooden forks and shovels are then used to toss the grain in the air to winnow out the chaff.

Diseases and Pests

Broad beans are susceptible to a large number of fungal diseases that may cause considerable crop losses. The most important of these are rust (*Uromyces fabae*), chocolate spot (*Botrytis fabae*), powdery mildew (*Erisyphe polygoni*), and root rot diseases (*Fusarium* and *Rhizoctonia* spp.). Several viral diseases have also been noted affecting the crop.

The major insect problems are the American bollworm (*Heliothis armigera*), which may be serious in late September and October, aphids (*Aphis fabae*), and thrips (*Teaniothrips sijotedt trybom*), which attack the reproductive organs and interfere with fertilization.

Weeds are also great problems in broad bean crops, resulting in severe yield reductions. Early removal is thus essential and two weedings are recommended.

Uses and Marketing

In many parts of Ethiopia broad beans are a daily part of the diet of the population. They are an important source of dietary protein, especially valuable during the numerous days of fasting that are observed. Broad beans may be consumed green, either raw, roasted, or boiled; as dry seed, having been soaked, roasted, or boiled; in a preparation with a hot sauce called "wot"; ground and mixed with barley, wheat, or teff flour to form "injera" (a kind of pancake-type bread); or used in the preparation of various sauces (e.g., in a mixture with mustard and spices that is fermented for 4–5 days).

The bulk of the broad bean crop is consumed locally, but a certain proportion is exported every year, particularly to the countries of the Arabian peninsula, western Europe, and Southeast Asia. The quantity and value of pulse exports over the past 7 years is shown in Table 2.

Field Peas (*Pisum sativum*)

The field pea is grown predominantly as a dry pulse but can also be harvested immature as a green vegetable. As with the broad bean crop, most of the production is consumed locally, with the exception of a small amount that is exported (Table 2).

In common with broad beans, peas are generally grown in areas between 1800 and 3000 m above sea level, and are normally sown at the beginning of the rains (mid-June to July) for harvesting from mid-October onward. The area devoted to field pea production is in general only slightly less than that for broad beans, but the considerable decline in yields over the past 6 years has meant that present production is very much lower (Table 1).

TABLE 2. Quantity ('000 t) and value (U.S. $) of pulse exports from Ethiopia 1970–77.

	Exportation									
	Chick-peas		Broad beans		Haricot beans		Lentils		Field peas	
Year	Quant.	Value	Quant.	Value	Quant.	Value	Quant.	Value	Quant.	Value
1970	2.2	235	15.6	225	17.1	396	15.8	312	0.4	257
1971	6.3	283	16.6	268	22.6	447	18.0	314	0.2	265
1972	10.7	279	19.0	299	25.6	402	21.9	322	0.5	284
1973	8.1	444	29.7	295	19.7	633	22.2	564	2.4	643
1974	8.2	682	28.0	489	46.0	1032	30.0	955	10.5	769
1975	10.0	539	22.0	404	41.5	622	37.3	832	–	–
1976	–	600	26.7	434	–	–	17.6	670	–	583
1977	10.0	171.5	26.7	264.6	–	–	17.6	641	–	–

Current Production Practices

The major production areas are in the north, west, and southwest of the country, and the crop is often grown on poor badly eroded soils where cereal production is not possible. Field peas are generally grown in monoculture but may be produced in a mixture with broad beans and occasionally also with barley. The crop is usually broadcast sown at the rate of 100–150 kg/ha (the latter figure being the recommended rate), and covered using a local plough. This practice, however, frequently results in uneven germination and the loss of young seedlings to both birds and ants.

Peas are harvested in a similar manner to broad beans, when the upper pods are yellowing and the lower ones are almost dry. Harvesting usually takes place in the early morning or afternoon to reduce losses from pod shattering and the cut plants are then stacked in the field to dry for 4–5 weeks before being threshed and winnowed.

Diseases and Pests

The diseases causing the most severe crop losses to field peas in Ethiopia are powdery mildew (*Erisyphe polygoni*), wilt (caused mainly by *Fusarium* species), and *Ascochyta* blight.

The most serious pest of field peas is probably the American bollworm (*Heliothis armigera*), but there is very little information available on the other important pests of the crop.

Weeds cause some yield losses, but weed control is rarely practiced and under good growing conditions the tall and viney Ethiopian peas compete fairly effectively with the weed population once complete ground cover has been achieved.

Highland Pulse Research

The agroecological systems existing within Ethiopia are highly complex in their structure, different ecological conditions being encountered within relatively short distances. As a result of this situation, a large number of trial sites must be used for experimentation to achieve proper representation.

The research and development work on food legumes is coordinated through the National Crop Improvement Committee, which evaluates research proposals prepared by the individual crop coordinators. Despite the importance of broad beans and chick-peas to the agriculture of the country, research on these crops is still in its infancy in Ethiopia.

Germ-plasm collections of both these crops have been built up as a result of collecting expeditions by a number of individuals and organizations. However, most collections to date have been predominantly from market samples and the information on such samples is generally very poor. In spite of this drawback, a considerable range of variation has been found within the collections and this has formed a useful base for improvement efforts. In fact some of the highest yielding lines developed so far have resulted from selections from such germ-plasm collections. In 1977, a systematic collection from the major growing provinces of Shoa and Gojam yielded more than 300 samples of broad bean and pea material. Further collection and systematic documentation, however, is required for both crops. In addition, broad bean germ plasm has been obtained from both national and international sources; in 1977–78, for example, 817 accessions from ICARDA, 81 from the USA, 50 from the U.K., and 129 from Ethiopia were screened by the program. Promising lines selected from such screenings are promoted into national level yield trials for further evaluation. Some cultivars have performed well in these trials: record yields of 40–50 quintals/ha have been reported, and under certain conditions the best cultivars have shown a two- to fourfold yield improvement over traditionally cultivated varieties.

The varieties and selections of broad beans and peas that have been shown to be superior to the presently cultivated types are for broad beans: Kuse 2.27.33, CS2DK, CS11AK, and CS38BK; for field peas: Prussian blue, CS436, Kulumsa, and Mahandar 4.

Agronomic trials have established that row planting of broad beans gives an increased yield over broadcast seeding over a wide range of seed rates. Studies on plant populations have been carried out both with broad beans and field peas and various seed rates and spacings have been recommended. Investigations have also revealed a significant interaction between date of planting, soil type, and seed yield in field peas, the best results being obtained with mid-June plantings on the red clay soils and early July plantings on the black clay soils.

Future Research Priorities

The average yields of pulse crops grown in Ethiopia's traditional pulse-growing regions tend to be very low (7–10 Q/ha) in comparison to yields obtained under experimental conditions (up to 50 Q/ha). This difference largely results from the continued use of local unimproved varieties grown under traditional agronomic means.

To increase yields at the national level, research on broad beans and field peas in the future must focus on two major thrusts: firstly and most importantly, the development of improved cultivars that combine a high yielding ability with resistance to the major diseases, insect pests, and frost, all of which are severe constraints to production; and secondly, the evolution and introduction of improved agronomic practices, such as proper seedbed preparation, accurate planting, and efficient weed control, which will enable the potential of these new varieties to be more fully expressed. Considerable emphasis will be placed on the development, testing, and distribution of such new cultivars and production practices and it is hoped that this will result in yields under commercial conditions that are more comparable to those at present being achieved on the research stations throughout the country.

Food Legumes in Syria

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Food legumes are considered to be important in the nutrition of both humans and livestock in most countries of the Near East and North Africa by virtue of their high content of both protein and carbohydrate. In addition, food legumes are important sources of minerals, such as iron, copper, and phosphorus, and vitamins. These crops are relatively inexpensive sources of dietary nutrients and have hence been named "the poor man's meat," which reflects their dominant position in the diets of a large part of the population of the country, especially the rural poor. Lentils are used in soups, salads, and various combinations with crushed rice and wheat, or vegetables and lemon juice, and chick-peas form a variety of foods, from homos (mashed with sesame oil and lemon) and falafel (mashed with peppers and fried) to sweets when covered with sugar.

Legume crops are also important for the benefits they provide both to soil fertility and structure, and therefore figure significantly in rotations throughout Syria. Furthermore legume grains provide the country with important export revenue.

Production and Marketing

Legumes are a very important crop in the agricultural economy of Syria and the annual surplus of supply over domestic consumption is exported to neighbouring countries (see Table 1).

Broad bean production in Syria is predominantly under irrigated conditions, which is reflected in the higher and more stable yields of this crop. In contrast to this, lentils and chick-peas are produced almost exclusively under rainfed conditions and their yields are consequently low and variable (Table 1).

Current Production Practices

In general, the planting of food legumes in Syria is considered to be semimechanized; the land is ploughed, usually by tractor, several times prior to planting, and fertilizer is applied at the rate of 250–450 kg of single superphosphate per hectare on irrigated land and 125–225 kg/ha on rainfed land. Fertilization is normally by hand broadcasting and usually takes place immediately before planting. Legume seeds are also generally sown by hand, lentils and chick-peas being broadcast into shallow furrows at the rates of 80–100 kg/ha and 80–150 kg/ha, respectively, and broad beans normally row planted at about 160–200 kg/ha. After sowing, the seed is covered by a cultivator to a depth of about 10 cm.

One or two manual cultivations are common during the season to control weeds and moisture infiltration.

Almost all the legume crops are hand harvested, left to dry in the field, and then transported to a hard area of ground where they are threshed, using an animal-drawn thresher, and winnowed. Seed losses may be considerable as a result of this procedure.

Research Activities

All investigations into legume improvement and production are the responsibility of

TABLE 1. Area (ha), production and exports (metric tonnes), and average yield (kg/ha) of grain legumes in Syria, 1972–76.

	Lentils					Broad beans					Chick-peas				
	Area					Area					Area				
Year	I[a]	R[a]	Prod.	Exp.	Yield	I	R	Prod.	Exp.	Yield	I	R	Prod.	Exp.	Yield
1972	2151	113949	96200	29555	835	3676	5659	12994	735	1559	191	44108	36422	1299	822
1973	1467	90614	23711	28530	258	2573	4169	7117	2153	1056	354	68130	27841	5281	407
1974	1722	83689	83369	14954	976	2781	4027	7251	1050	1509	427	90282	60265	11651	664
1975	2641	95203	66624	10097	681	3966	1859	9336	1203	1603	581	54608	26698	8463	484
1976	6061	140418	136227	21756	930	4833	3372	13690	–	1669	518	67035	50753	2591	751

[a] I = irrigated conditions; R = rainfed conditions.

the Directorate for Scientific and Agricultural Research, which carries out its studies at centres in 11 of the 16 governates into which the country is divided.

The main emphasis of food legume research in Syria is on improving legume varieties through the testing of introductions and local cultivars, segregating generations of crosses and promising selections throughout the country on the basis of yield, disease resistance, and adaptation to the various production regions.

To date, the research program has isolated 18 local varieties of broad beans and seven of lentils that have been subjected to comparative tests to determine their yielding ability and adaptation. In addition to this work, the research efforts on chick-peas have resulted in the introduction of three improved varieties, namely Nobokho, Koliakan, and Registered 466.

Critical Constraints to Production

Perhaps the most serious problem facing legume producers in Syria is the very costly reliance on hand labour for most production operations, especially at harvest time when labour is both scarce and expensive. This, coupled with the unavailability of sufficient improved and adapted varieties exhibiting tolerance to adverse climatic conditions, disease and pest resistance, and good seed qualities, is making legume crops increasingly less economic to produce and resulting in producers favouring the more economic and proven cereal production enterprises. In addition, it has been noted that workers continually involved in legume production may develop bad allergic reactions.

Priorities for Production Improvement

Recognizing these major production problems, the research efforts of the Directorate are being focused on the identification of high-yielding disease-resistant varieties that have a good adaptation to the production conditions of the different parts of the country. To ensure that improved legume varieties reach the producers, who must use them if improvements in overall production are to result, it will be essential to considerably strengthen the capabilities of the seed multiplication and distribution network. Furthermore, the urgent problems of insufficient and inadequate production equipment and outmoded production practices must be solved to enable legumes to compete as an economic crop in the agriculture of the country.

Food Legume Improvement in the People's Democratic Republic of Yemen

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The People's Democratic Republic of Yemen, lying between latitudes 12.40°N and 19.00°N and longitudes 43.30°E and 53.00°E, covers an area of 310 km², of which only 1% is suitable for agriculture. The climate is hot, with the humidity varying from high in the coastal areas to very low inland. Sand storms and high winds are major agricultural problems, especially in the months of June and July. Mean maximum temperatures, recorded at the El-Kod Research Station (35 miles from Aden) vary from 35.08 °C in the summer months of May to September to about 20.60 °C in the winter (October–April). The coastal areas receive only light showers in the winter, and the annual rainfall in these areas varies between 25 and 63 mm. In contrast to this, the mountainous region receives up to 346 mm of rainfall per year, concentrated mainly in the summer months.

Agricultural activities are largely concentrated in the big wadies and deltas where the soils consist of deep and fertile alluvial silts. Because rainfall is insufficient to support the cropping, almost all production is irrigated by flood water in the summer and, to a lesser extent, also in the winter. This flooding acts as a regulator to the acreage of crops that can be grown in any given area, and makes annual production extremely variable. To achieve greater stability in the cropped area, government schemes are at present bringing large areas of cultivatable land into use through tube-well irrigation. Problems of salinity, however, are likely to become increasingly important, as much of the irrigation water is already of a very high salt content. This will severely limit the choice of crops that can be grown under these schemes.

Currently the actual area under cultivation ranges between 100 000 and 150 000 ha. Of this, about 60% is under spate irrigation, and the area under well irrigation, although still limited, is increasing rapidly. In the coastal areas, the main field crops are cotton, maize, sorghum, and tobacco, together with vegetables, such as tomato and cucurbits, and fruits, which include banana, mango, and papaya. The cropping in the mid- and high-altitude plains consists mainly of wheat, sorghum, potato, tomato, and various citrus and stone fruits.

In general, legumes are not considered to be economically important crops in Yemen and have consequently received very little research attention and few incentives to production. However, alfalfa is an undeniably important fodder crop throughout the country and the need for other crops, apart from sesame and cotton, for oil extraction is at present creating an interest in the introduction of groundnuts. This, together with the undoubted nutritional importance of the small areas of dry legumes grown for domestic consumption by many farmers, has prompted the agronomy section of the El-Kod Agricultural Station to initiate work on pulse crops.

Work commenced in the 1974–75 season with the multiplication of varieties of cowpea and green gram. Experiments using green gram intercropped with cotton have so far proved disappointing, showing no beneficial effects of this treatment on the incidence of *Rhizoctonia* root rot on cotton and a significant increase in pest problems. Initial trials on groundnut were also started in this season, and during 1975–76, 13 varieties introduced from the USA, Sudan, East Africa, Egypt, and India were evaluated for their performance under local conditions. Results have shown the varieties NC2 and Ashford to be particularly promising and future prospects for increasing the popularity of this crop are encouraging. Thirty-nine varieties of cowpeas, mostly received from the International Institute of Tropical Agriculture (IITA) in Nigeria, were also tested in the 1975–76 season in three separate trials designed to identify suitable varieties for planting in different seasons. Evaluations of these varieties on the basis of grain size and colour, which partly determine consumer acceptability, were also carried out. Results have indicated some promising varieties and shown that seed yield can be raised from 1 to 2.2 tonnes/ha. Seven varieties with red seed and white seed with black spots, which are likely to receive consumer acceptability, have already been identified.

In view of the very limited amount of land available for agriculture in the country, the People's Democratic Republic of Yemen is expanding its efforts to intensify and develop its agriculture. The search for new, highly productive, and nutritious crops is creating increasing interest in the legumes, which are proven in this field under small-scale cultivation. The challenge now facing the country is to achieve these benefits as part of a much wider and larger scale of production.

Food Legume Production in Libya

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In comparison with other food crops, such as wheat and barley, the production of legumes in Libya takes place on a very small scale. Even the most important of these crops, namely broad beans, is only cultivated on an average annual area of about 4000 ha, a figure that has remained static for the past 10 years. Together with the other pulse crops, which include lentils, field beans, and peas, broad bean cultivation is confined to the northern part of the country along the Mediterranean coast. In this strip of land, which varies from 4 to 40 km in width and extends the length of the country from Tunisia in the west to Egypt in the east, the annual rainfall ranges between 250 to 300 mm and temperatures fluctuate from 25 to 30 °C. The soils are generally sandy with occasional patches of clay or gypsiferous, and many farms rely almost completely on groundwater for their crop production.

With this very limited production situation, the bulk of the country's consumption requirements are imported from its neighbours.

Both large- and small-seeded types of broad beans are grown and varieties include Local land 40, Cyprus, and Sax. The crop is consumed as green pods, green seeds, or dry seeds. The production of lentils, which used to be on a fairly large scale to provide animal feed, has decreased considerably in recent years with the increasing popularity and availability of alternative fodder crops, and at present Libya has to import its total requirements. Peas are, however, grown on a somewhat greater area for seed, with varieties such as Sidi Masri 1 and 2 and Little Marvel dominating. Field bean varieties include Stringless Blue Lake and FAO, but bean production is of very little importance in the country.

The production of food legumes is severely limited by several constraints, which include the total lack of research emphasis on the crops and the corresponding lack of trained research personnel; the low and variable fertility and salinity problems of many of the soils; the great variability of annual rainfall and the shortage of irrigation water; disease problems that reduce production in years of adequate rainfall; and the scarcity of hand labour coupled with the difficulty of mechanizing production, which is resulting in greatly increased production costs and rapidly making the crops uneconomic to produce.

The way to expansion in food legume production in Libya lies in placing considerably more emphasis upon research into these critical problem areas. In recognition of this, a committee composed of representatives of the Agricultural Research Centre, the Faculty of Agriculture of the University of Tripoli, and the Ministry of Agriculture has recently been established and has recommended that legume research and production be promoted throughout the country. This is a first, vital step and the way is now clear for increased cooperation with organizations such as ICARDA, FAO, and ACSAD to build up a base of personnel and material with which to form the foundation of a strong future development program for these hitherto neglected but vitally important crops.

Status of Food Legume Production in Afghanistan

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Afghanistan is a mountainous country with a dry climate. Rainfall ranges from 100 to 400 mm annually, with the exception of some high altitudes, where it may reach 1200 mm. The climate ranges from hot subtropical desert in the south, through semi-arid and continental Mediterranean types in the central areas, to continental desert in the extreme north of the country. Figure 1 shows the provincial divisions of the country.

Afghanistan has been classified into four major ecological zones on the basis of physiography, climate, soils, and present and potential land use. These are as follows:

(1) the Mazari–Sharif zone, an area of 30 000 km^2 in the north of the country with a semi-arid continental Mediterranean-type climate and an annual rainfall of 200 mm concentrated in the winter and spring; the elevation varies between 200 and 500 m above sea level and the soils are calciferous, loamy, and deep with a reasonable level of organic matter; the predominant crops are wheat, cotton, rice, sugarbeet, and maize;

(2) the Central Mountain zone, which includes all the mountainous area with elevations of above 2000 m; the terrain is mainly hilly and steeply sloping, interspersed with mountain valleys, and the climate is semi-arid Mediterranean

Fig. 1. Provincial divisions of Afghanistan.

with a mean annual precipitation of 250–400 mm occurring predominantly in the winter months; the soils are very shallow on the upper slopes, loamy or clayey with gravel and stones on the lower slopes, and deep and loamy in the valley bottoms; wheat, melons, and deciduous fruits are grown under irrigation;

(3) the Farah-Kandahar zone, covering the whole of the Herat and Chakhansur provinces and the northwestern part of Helmand province in the southwest of the country; the elevation ranges from 200 to 2000 m and the zone can further be subdivided on the basis of this range to include (a) the foothills, with elevations of between 1000 and 2000 m. The mean annual precipitation varies between 100 and 200 mm and the soils are loamy or clayey, moderately to strongly calcereous, with a marked zone of lime accumulation. When sufficient water is available, wheat, maize, melons, pomegranates, grapes, and some alfalfa are grown; (b) the nonsaline plateau, 500–1000 m above sea level and with a gently rolling hilly relief. The climate is subtropical and arid, and the soils mainly calcereous, silty loams, or silty clays, again with a strong zone of lime accumulation. The main crops are wheat, millets, and melons grown under irrigation; (c) the Playa, which is a nearly level concave area in which the soils are strongly saline and where, as a consequence, the vegetation consists almost exclusively of bushes that thrive under salt conditions.

(4) the Registan Zone, in the southeast, which is a sandy desert with an arid climate where annual rainfall is only 100–150 mm; the land is used for little else apart from rangeland grazing of livestock.

Of a total land area of 64.75 million ha, only 7.95 million (12.28%) is potentially arable. Much of this remains fallow for long periods due to insufficient moisture and only the 2.44 million ha that are under irrigation are cropped regularly. Crop production in Afghanistan is dominated by the cereals (wheat, maize, rice, and barley) that occupy 44% of the arable area. Other important crops include cotton, pulses, fruits, and vegetables (see Table 1).

It has been reported that chick-peas (*Cicer arietinum*), lentils (*Lens culinaris*), broad beans (*Vicia faba*), mungbean (*Vigna radiata*), dry bean (*Phaseolus vulgaris*), pea (*Pisum sativum*), and chickling vetch (*Lathyrus sativus*) are the main food legume species cultivated in Afghanistan, but there are unfortunately no statistics available on the area, yield, and production of these crops.

Very little research has been carried out on grain legume crops in Afghanistan. However, various germ-plasm collection expeditions have yielded some information about the relative importance of the legume crops within the country:

Chick-pea (*Cicer arietinum*) is the most important pulse in Afghanistan and is grown under both irrigated and rainfed conditions in the Badakhshan, Balkh, Takhar, Herat, Kunduz, and Kandahar districts.

Peas (*Pisum sativum*) are grown over a very wide range of conditions in Afghanistan and may be cultivated up to altitudes of over 3000 m. Twenty botanical varieties, all small seeded and green in colour, have been reported.

Lentils (*Lens culinaris*) are the second-most important cultivated grain legume in the

TABLE 1. Area ('000 ha), yield (kg/ha), and total production ('000 metric tonnes) of major crops in Afghanistan as reported in FAO production year book 1976.

Crop	Acreage	Yield	Prod.
Wheat	2400	1229	2950
Maize	490	1612	790
Barley	390	1026	400
Rice (paddy)	210	2143	450
Cotton	150	1067	160
Pulses	35	1624	57
Sugar beets	9	12941	116
Sugarcane	2	37859	55

country. They are grown predominantly at intermediate altitudes, between 500 and 2400 m, and mainly in eastern Afghanistan.

Broad beans (*Vicia faba*) are cultivated mainly in the upland areas and are the principal food of the mountain population. In the Bamyan district, for instance, they are second only to wheat in importance. Broad beans may be grown in a mixture with barley, peas, and *Lathyrus*, and are characteristically small seeded and dark in colour.

Mungbeans (*Vigna radiata*) are grown under irrigated conditions in Badakhstan, Badghis, Baghlan, Balkh, Kunduz, Kandahar, and Nangrahar. In the latter province they are grown in a mixture with maize and used as fodder for oxen.

Of the other grain legumes grown in Afghanistan, cowpeas and *Phaseolus* beans are primarily grown under irrigated conditions and chickling vetch under rainfed conditions in the Balk, Kabul, Herat, Kunduz, Hilmand, and Nangrahar provinces.

Peas, *Phaseolus* beans, and broad beans are consumed as both green and dry seed, whereas lentils, chick-peas, and mungbeans are eaten only in the dry state. Lentils are used in soups, cooked with meat and rice, or cooked alone and served with oil, onions, and garlic. Chick-peas are commonly eaten as a snack; boiled and served with salt, pepper, and vinegar; cooked with meat and served with rice; cooked alone and eaten with bread; covered with candy and eaten as sweets; or mixed with wheat flour in the preparation of "Pickawara." Broad beans are generally eaten alone as a snack or with onions and garlic; peas and dry beans are consumed with meat or cooked with "ashak"; and mungbeans are mixed with rice and cooked as "Mujaddara" or dehulled, cooked, and eaten as a vegetable.

Because there has been so little work carried out on grain legumes in Afghanistan, the major production problems cannot be confidently enumerated. However, utilization problems concerning cookability are of major importance in determining acceptability amongst the population. The major pest and disease problems recorded include rust, root rot, powdery mildew, and aphids on broad beans, and root rot, aphids, and pod borers on chick-peas.

Considerable work in both research and extension will be required in the future, first to define the major production problems, and then to increase the popularity of these crops with the farmers so that they can provide a valuable complement to cereals in rotations and assist in bringing much of the presently fallowed land into more intensive cultivation.

Food Legumes in India

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India possesses the largest area in the world under grain legume cultivation. Grain legumes have proved to be the mainstay of Indian agriculture for the past few decades, enabling the land to produce reasonable quantities of food grains despite the almost total lack of manuring or fertilization. This has primarily resulted from the legumes' ability to fix atmospheric nitrogen, which gives them a comparative advantage under these growing conditions. In addition to this, as a group the legumes exhibit considerably higher drought tolerance than other crops and have thus found a niche in areas characterized by regular moisture stress. Because of these characteristics, legume crops are invariably included in rotations throughout the country and also figure prominantly in crop mixtures.

Apart from these agronomic advantages, grain legumes occupy an important place in dietary considerations, supplying, as they do, most of the protein requirements of India's predominantly vegetarian population. Some of the crops also serve as excellent forages and grain concentrates in the feed of the country's large cattle population and others are favoured for use as green manures.

Production Position

In 1976, the area under pulse crops was approximately 24 million ha, or 20% of the total area under food grain crops, and the production from this was about 13 million tonnes. The major pulse crops and their relative importance to Indian agriculture are given in Table 1.

Chick-pea is by far the most important food legume crop in India, occupying an area of 8.37 million ha throughout the country. The others are of less importance overall, but

TABLE 1. Major pulse crops of India and their relative importance in the country's agriculture.

Crop		% of total	
Botanical name	English name	Area (ha)	Prod.
Cicer arietinum Linn.	Gram or Bengal gram	41.0	51.0
Cajanus cajan (Linn.) Millsp	Pigeon pea or red gram	9.8	11.2
Lathyrus sativus Linn.	Chickling vetch	7.9	7.6
Vigna mungo	Black gram	6.5	3.9
Dolichos biflorus Linn.	Horse gram	6.3	3.0
Phaseolus aconitifolius Jacq	Moth	6.2	2.6
Pisum arvense Linn. and *Pisum sativum* Linn.	Peas	5.4	9.8
Vigna radiata (L) Wilczek	Green gram	5.4	2.5
Lens culinaris Mebic.	Lentil	3.3	2.9
Other pulses[a]			

[a] Includes: *Vigna unguiculata* L. (cowpea), *Cyamopsis tetragonoleba* L. (clusterbean), *Dolichos lablab* L. (Indian bean or field bean), *Phaseolus vulgaris* L. (French bean), *Phaseolus trilobus* L. (pillipesara), *Glycine max*. L. (soybean).

each crop has its own unique place in the agriculture of the country dependent upon its suitability for particular rotations and crop mixtures and/or its adaptation to specific agroecological conditions. Among the less widely cultivated pulses for example, cowpea and *Phaseolus* bean are grown in most regions of the country, whereas soybean is a staple pulse only in the temperate regions of the Himalayas. Similarly, french bean cultivation is restricted to regions with a cool monsoon season; guar is an important field crop in the western part of the Indo-Gangetic Plain in the north; and pillipesara assumes more importance in the south of the country. The cultivation of some crops (e.g., soybean), which are relatively more productive and tolerant to adverse conditions, is now tending to spread from their more traditional niches into the plains of northern and central India.

Madhya Pradesh, Uttar Pradesh, Rajasthan, Mahrashtra, and Bihar are considered to be the most important food legume-growing areas in the country (Fig. 1).

Agronomic and Nutritional Uses

Pulses as Food and Fodder

In most parts of India, pulses form an essential part of the daily diet of the population and serve as the major source of dietary protein. They are thus used as food in a wide

Fig. 1. Provincial divisions of India; Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, and Bihar are the most important food legume-growing areas in the country.

variety of forms. The most common of these is soup; the split grains are boiled in spiced water and seasoned to form "dal" or "sambar." The grains may also be ground and boiled, roasted or fried; sprouted and then cooked; made into sweetmeats; or used as a flour in the preparation of bread and other foodstuffs. The grain and pods of some pulses (e.g., pea, guar, cowpea, and *Phaseolus* beans) are often cooked and eaten in the green condition. It is largely the brown seeded desi types of chick-pea that are cultivated for human consumption in India; the pink, green, and black kabuli types are used only to a very limited extent in the country.

Some of the pulse crops, such as guar, cowpea, pea, chickling vetch, horse gram, and pillipesara, are commonly used as fodder for draft and milk animals. Legume grains are also used to some extent as concentrates in the diets of animals. Guar grain is especially preferred for this purpose for draft animals and chick-pea is held in high esteem for feeding bullocks and horses.

Pulses as Green Manures

Legume crops, such as green gram, clusterbean, cowpea, and pillipesara, are excellent green manure crops, although their use for this purpose is secondary to that of the well-recognized green manure sunn hemp (*Crotalaria juncea*). This is mainly because they provide less organic matter, and hence possibly also less nitrogen, to the soil when turned in. However, they are considered to be very useful as manures because, by virtue of their rapid rate of decomposition, they become thoroughly incorporated into the soil at a much faster rate than the more woody, conventional green manure crops.

Pulses in Crop Mixtures and Rotations

Their ability to thrive under a wide range of soil and climatic conditions ensures the legumes an important place in a large number of crop mixtures and rotations throughout India.

Pigeon pea is generally grown in a mixture with millets or cotton, or as a border crop in sugarcane fields. In the northern and central parts of the country, where late (250-day) or medium (200-day) maturing varieties are grown, they are almost invariably mixed with millets such as "jowar" (*Sorghum vulgare*), "bojra" (*Pennisetum typhoides*), or "kodon" (*Paspalum scrobiculatum*). Sometimes a small proportion of other crops, such as green gram, black gram, or sesamum, are also added to the mixture. These mixtures are normally broadcast sown in the months of June or July, depending upon the onset of the monsoon. During the first 4 months, the more rapidly growing millet is the dominant crop, but after the millet harvest in October–November the pigeon pea crop grows rapidly to give complete field cover by the end of the winter season. As it flowers and forms pods after the associated millet crop is removed, and has a full season in which to complete its growth and development, the pigeon pea crop recovers well from its earlier cramping, giving reasonable yields. The sowing of this mixture is popular throughout the country as it enables two, or sometimes more crops to be grown within one season under dryland farming conditions; it also causes a marked reduction in the incidence of wilt disease in pigeon pea plants. Although generally grown as a single crop, chick-pea is often sown in a mixture with wheat, barley, linseed, or mustard in the unirrigated areas of Uttar Pradesh and Madhya Pradesh. This is primarily because, having a deeper rooting system than cereal crops, the chick-pea component of the mixture provides a certain amount of guarantee against crop failure in the event of the winter rains being insufficient to support the cereal component. Similarly, horse gram is usually grown as a single crop, but is often grown in a mixture with castor, groundnut, or cotton in Karnataka and other areas. Other legume crops commonly included in mixed cropping regimes include short duration varieties of black gram with maize; field bean (*Dolichos lablab*) in "ragi" (*Eleusine coracana*) mixtures; and cowpea and black gram with millets and oilseeds.

Grain legume crops figure prominently in rotations all over India. They may occupy a field once in every 2 or 3 years or often even more frequently, because of their ability to grow well under conditions of limited soil moisture and at the same time improve soil fertility. In Northern India rotation of dryland paddy, which matures in 80–90 days, with chick-pea is a widespread practice. Where the paddy crop is of a long duration, however, field pea (*Pisum sativum*) or *Lathyrus sativus* replaces the gram crop in the rotation.

To ensure good germination of the legume crop in this rotation it is customary in the important paddy-growing areas of Bihar, Orissa, and Madhya Pradesh to sow the pulse into a standing paddy crop just prior to harvest when the soil is still wet. However, the crop most commonly involved in this rotation, *Lathyrus sativus*, contains a neurotoxin, which may accumulate in the body and cause paralysis of the lower limbs (lathyrism). It has proved hard to identify an alternative to replace *Lathyrus* in the rotation, as this crop is ideally suited to growing in paddy soils, which on drying become as hard as steel and when wetted are quickly waterlogged. Such conditions preclude the utilization of chick-peas, lentils, or peas, which are sensitive to both drought and overwatering. Investigations continue and results to date indicate that some lentil varieties that are better adapted to these conditions might be used to replace the currently grown *Lathyrus* cultivars. A recently developed low-neurotoxin *Lathyrus* line (Pusa 24) might also be used as a replacement.

Under rainfed conditions chick-pea and lentil are almost invariably grown as a single crop in rotation with a cereal, millet, oilseed, or cotton, depending upon the region. In irrigated areas, however, double cropping is frequently practiced. This has been made possible through the evolution of short duration genotypes of green gram, black gram, and cowpea, which are also tending to popularize multiple cropping under rainfed conditions, especially on land that usually remains fallow for 5–6 months of the year.

Pulses and Soil Improvement

The value of leguminous crops to Indian agriculture, by virtue of their ability, in symbiosis with *Rhizobium* bacteria, to fix atmospheric nitrogen and supply it to the soil, is immense. Some of the nitrogenous compounds formed in this way are able to pass into the soil in the vicinity of the plant roots. These compounds are easily assimilable by nonleguminous plants, and the advantages obtained by crops grown in association with legumes may be one of the major reasons for their popularity in crop mixtures.

Besides their undoubted contribution to soil fertility, grain legumes have a considerable improvement effect on soil structure, their deep and extensive rooting systems opening out the subsoil layer and providing a large amount of organic matter to this layer upon death or shedding. Such deep rooting systems and spreading growth habits also mean that the legumes are important for their erosion-resistant properties. This attribute is often exploited by planting legumes either singly or between spaced rows of other crops on erosion-prone soils.

Unfortunately, however, the fact that food legume crops possess such important agronomic advantages is tending to mitigate against achieving yield improvements in many parts of India. This results from the farmers' traditional and continuing reliance upon legumes to replenish soil fertility, to assist other crops, to reduce soil damage and erosion, and to produce yields from very marginal lands, under minimum input conditions. In using legumes in this way it is often forgotten that, in common with other food crops, high soil fertility is required for the production of high yields. There is thus considerable potential for yield improvement in India, and indeed throughout the Middle East, through the widespread introduction of improved methods of agronomy, especially phosphate fertilization, coupled with an inherent change in the way that legume crops are perceived at the farmers' level.

Section III
Disease Problems
on
Legume Crops

Diseases of Major Food Legume Crops in Syria

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Broad bean (*Vicia faba*), lentil (*Lens culinaris*), and chick-pea (*Cicer arietinum*) are the major food legume crops grown in Syria, and have been used for thousands of years as major sources of low-cost protein food for both human and livestock consumption. They are produced on average areas of 15 000, 140 000, and 70 000 ha, respectively and thus contribute considerably to the agriculture of the country. Lentils are grown predominantly in the northern and central areas of Syria, whereas the production of chick-peas is concentrated in the southern provinces. Broad beans are cultivated throughout the country under a very wide range of environmental conditions and are frequently irrigated, unlike the other two crops, which are almost exclusively produced under rainfed conditions.

The yield and quality of these important crops are affected appreciably by a number of diseases that, depending on weather conditions, host susceptibility, and pathogen virulence, may cause severe losses in certain seasons and at certain locations. Of the three crops, broad bean is the most severely affected, followed by chick-pea and then lentil. Disease severity is usually greater in the coastal districts of Syria, where both rainfall and humidity are higher, as opposed to the drier areas of the interior. For this reason, this report, which aims to analyze the disease situation in the three major legume crops in Syria in an attempt to identify the most important disease problems and to indicate research priorities geared to their solution, is based mainly on studies conducted in the coastal districts. It involves the locational spread and severity of broad bean diseases, the development of these diseases as related to planting date, and observations on disease-screening nurseries of lentil, chick-pea, and broad bean.

Diseases of Broad Beans

The importance of diseases as a major limiting factor in broad bean production has become clear throughout the world in recent years. Broad beans in Syria are affected by a number of diseases including root rot/wilt complex, chocolate spot, *Ascochyta* blight, *Alternaria* spot, rust, powdery mildew, and several viruses. Local cultivars of the crop are generally susceptible to many of the pathogens, and diseases of one type or another are evident on almost all farms.

Disease Survey

In an attempt to analyze the disease situation and identify the major broad bean disease problems, a preliminary survey was conducted during the 1976–77 season in the coastal districts of the country. Representative collections of 10–15 diseased plants were taken from each of 61 fields distributed along 130 km of the region from north to south. Disease development was encouraged in the diseased plant parts through incubation under moist and favourable conditions and the pathogens involved were identified by microscopic examination of these parts. Diseases were recorded as being present when the specimen showed both the characteristic symptoms and the causal organisms of the particular diseases. This survey indicated the presence of two viral and six fungal diseases, as follow.

Viral Diseases

Diseases caused by viral pathogens were characterized by two distinct patterns of symptoms, namely, blotching of the young leaves with light and dark green areas, producing a mottled mosaic pattern; and yellowing and curling of the upper and younger leaves. No attempt was made to purify or identify the causal organisms.

Fungal Diseases

Rust–Small light-coloured pustules on the leaves, developing into well-defined circular reddish pustules, containing thick-walled, single-celled, oval spores on long stalks indicated an infection of rust, apparently caused by *Uromyces fabae*. The disease was very widespread during the season under consideration, being present in 93% of the sample fields. It was rarely identified early in the season, but became severe in February and March, causing considerable defoliation. However, yield losses are probably slight except on late planted crops, as the disease appears late after many of the pods have already been set.

Chocolate spot — Starting as small, well-defined, slightly sunken, reddish spots, 2–5 mm in diameter with dark brown margins, the characteristic symptoms of chocolate spot become larger later in the season and may coalesce to form irregular and dark lesions. These symptoms were resolved into two distinct types of host reaction: small, brown, well-defined spots; and darker, coalesced lesions. Whether these two reactions are due to different strains of the pathogen or to differences in host physiology at the time of infection has still not been determined. Under microscopic examination, the oval/spherical, single-celled conidia borne in clusters at the tips of irregular conidiophores indicated *Botrytis fabae* as the causal agent. The disease was widespread and reached epiphytotic levels in December and January, a period characterized by cool and humid weather and the formation of dew on broad bean leaves. It was present in 86% of the sample locations and was probably the most destructive of the diseases studied in the 1976–77 season. A comparison of a sample of heavily infected plants with a similar sample of disease-free material indicated losses of up to 75% in the green seed weight of the crop. Furthermore, during extended periods of cool wet weather, infection caused total crop loss. Chocolate spot has been controlled successfully in certain parts of Syria by the application of dithiocarbamate fungicides. However, a similar approach to control in the coastal areas has failed, due presumably to the rapid washing off of the chemical from crop leaves as a result of the higher precipitation in these areas. The use of dithiocarbamates combined with a sticking agent is currently being tested as a way around this problem.

***Ascochyta* blight** — The symptoms of the disease, namely circular/oval, tan-coloured spots with dark margins containing small black pycnidia, and the examination, which revealed the presence of masses of oblong, one to two septate spores, confirmed that the infection was caused by *Ascochyta fabae*. This disease also reached epiphytotic conditions during January and February and was found in 85% of the samples. Although the symptoms were mainly confined to the leaves, pod and stem infections were also observed, and appreciable losses were apparent. *Ascochyta* blight is a seed-borne disease and isolates of the pathogen obtained from local seeds have been shown to possess a high degree of virulence in artificial inoculation trials. The use of clean seed is therefore an important step in minimizing infection and reducing yield losses caused by this disease.

Brown spot — The causal agent of this disease was identified as an *Alternaria* species from the characteristic circular, dark-brown lesions with concentric markings and a surrounding halo of pale tissue and the brown chains of clavate, septate conidia that these lesions contained. The lesions were mostly confined to the lower leaves during the early part of the season, but spread to the upper leaves and pods as the season progressed. The disease was encountered in 84% of the sites and its severity appeared to be enhanced by interactions with *Botrytis fabae* and *Ascochyta fabae*, which seem to predispose the host to infections by *Alternaria* spp.

Powdery mildew — Chlorotic leaf spots with a covering of powdery grey mycelium, consisting of hyphae and conidiophores bearing one-celled conidia, indicated that these infections were probably caused by *Erysiphe polygoni*. The disease was of minor importance during the 1976–77 season, as weather conditions did not favour disease development, and only 5% of the sample locations were found to be infected.

Black root rot/wilt complex — Plants infected by this complex of diseases exhibit general wilting and collapse. Infection usually occurs in isolated loci but in severe cases most plants in the field become infected, stunted, and may die before flowering. Preliminary identification of the causal agents indicate that this complex is caused by a number of different pathogens. So far, several fungi, namely *Rhizoctonia* spp. (from the necrotic xylem), *Phialophora* spp. (from the pith tissue at the base of the stem), and a *Pythium* spp. (from the roots of seedlings) have been isolated from infected plants. About 77% of the sample fields were infected, and, even though loss can be severe, it is highly dependent on the stage at which the plant is attacked, younger plants in general being more susceptible than older ones. In addition, it appears that heavy soils tend to favour disease development, probably due to their superior water-retention characteristics.

Disease Development and Planting Date

By altering dates of crop planting, the relation between susceptible stages in the host, environmental conditions, abundance of disease inoculum, and the incidence and development of infections can also be changed. Investigations with local broad bean varieties planted on 10 December, 25 December, 10 January, 25 January, and 18 February have indicated that the severity of *Ascochyta* blight, chocolate spot, and root rot decreased significantly with delay in planting. These decreases may have been associated with the decreasing precipitation, increasing temperatures, or changes in relative humidity that occurred during the period under consideration. No statistically significant differences were detected between plantings in the development of *Alternaria* leaf spot, although earlier plantings showed slightly lower levels of infection than the later ones.

Differences in disease development between dates of planting were probably due in part to differences in the susceptibility of the broad bean plants at different stages of growth and the abundance of disease inoculum at these stages, as well as to the environmental considerations already mentioned. Additional research is needed to understand the development of these diseases in relation to the physiological growth stages of the host plants, so that control methods based on cultural practices can be put on a much more rational base.

Diseases of Chick-peas

Chick-peas grown in Syria are affected significantly by both the diseases of the root rot/wilt complex and *Ascochyta* blight. Disease severity is greater in the coastal zones, but as this crop is grown predominantly in the drier south of the country, disease considerations may be less important than in broad beans, which are cultivated under conditions much more beneficial to disease preservation and development.

Root Rot/Wilt Complex

As with broad beans, preliminary attempts to identify the causal agent have revealed the association of a number of fungi with the disease. These include *Rhizoctonia* sp. (isolated from the tap roots), *Fusarium* sp. (from the vascular tissue), *Peyronelleae* sp. (from the stem near the soil surface), and *Phialophora* sp. (from the lateral roots). Work is currently under way to confirm the association of these organisms with the disease and to establish their pathogenicity. Losses due to root rot/wilt complex are difficult to estimate, but it is evident that severity is greater on plants grown in heavy and wet soils, and on the crops planted early, during the rainy part of the season.

Ascochyta Blight

This is probably the most important disease of chick-peas in Syria, especially in years when the rains continue late into spring. It can be very destructive in the humid coastal districts where rainfall is high and may be particularly severe in crops that are early sown in

November. Close examination of diseased tissue has shown the causal organism to be *Ascochyta rabiei*.

Stemphylium

Attack by species of *Stemphylium* results in chlorosis of the leaves followed by necrosis of their tips. The disease is considered to be of minor importance and is normally found only on leaves of plants already infected with root rot. It appears that root and stem infections by pathogens of the root rot/wilt complex increase the susceptibility of the plants to infection by this organism.

Diseases of Lentils

Of the three major pulses grown in Syria, lentils are least affected by diseases. A few, however, including root rot/wilt complex, downy mildew, rust, and *Ascochyta* blight, have been observed on farmers' fields.

Diseases caused by the pathogens of the root rot/wilt complex are probably the most important of these. Infection is more severe in the coastal districts but, as lentils are primarily grown in the inland areas with lower rates of annual rainfall, losses are rarely very appreciable. One causal agent has been preliminarily identified as *Phialophora* sp., which was isolated from necrotic stem and root tissues. However, it seems likely that other pathogens, such as *Rhizoctonia* and *Fusarium* sp., are also associated with this disease complex. More work on isolation and pathogenicity testing is required before any firm identification can be made. As in chick-peas, infections by root rot/wilt pathogens appear to render lentil foliage more susceptible to attack by *Stemphylium* sp.

At present, detailed information on the distribution and economic importance of downy mildew (*Peronospora* sp.), rust (*Uromyces fabae*), and *Ascochyta* blight of lentils is not available. These diseases do not seem to have precipitated major losses as yet but may remain as a potential problem in lentil-producing areas.

Research Priorities

In Syria, disease infection constitutes one of the most important constraints to the production of broad beans and, to a lesser extent, chick-peas and lentils. The disease situation in the country is complex and considerably more studies, especially disease survey programs, similar to that initiated in the broad bean-producing coastal areas, should be conducted throughout Syria in the major legume-producing areas. These surveys will enable the identification of the disease problems of significance, their distribution, and economic importance. Survey work to ascertain the countrywide importance of virus diseases and their insect vectors *Aphis* sp. will also be necessary.

Information gained from this survey work will help to concentrate research activities on the problems of prime importance and provide a valuable base from which the development of effective disease control strategies for different diseases and locations can proceed. At present no resistant cultivars are available for local production and thus considerable emphasis should be placed on the identification of sources of resistance, the incorporation of this resistance into improved varieties, and increasing the availability of these varieties to the farmers. Due to its very favourable environment for disease development, the coastal district of Syria is an excellent location for work of this type. However, in support of this emphasis, much work still remains to be done on screening techniques and methods of creating artificial epiphytotic conditions in the field, before reasonable advances can be expected. With the present undeveloped state of breeding work aimed at the production of resistant varieties, short-term efforts should also be geared toward development of chemical controls together with modified agronomic practices, including measures to control various weed reservoirs of inoculum, whereas long-term research should focus more on an integrated control strategy in which resistant varieties play the major role.

Besides its more obvious effect on seed yield, disease can also affect seed quality and hence the price that the farmer receives for his produce. Seeds infected with *Ascochyta*, for example, are covered with brown spots and thus have a low market value. The relation between disease infection and seed quality, in terms of protein quantity and quality, and the presence of antinutritional factors need study, and quality considerations must be taken into account in determining the economic feasibility of various disease control measures.

Much work remains to be done, but recognition of the magnitude of the problem and the critical areas of importance within it are enabling research to focus itself much more finely on providing solutions to the specific disease constraints, which at present prevent a greatly increased production of these important food crops in Syria.

Food Legume Diseases in North Africa

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Food legumes have been important crops for some considerable time in the countries of North Africa, and recent increases in demand for dry pulses in Western Europe appear to be promoting a renewed interest in these crops. Food legumes provide a valuable source of dietary protein to the population and also play an important role in maintaining soil productivity in rotations by accumulating plant nutrients, such as nitrogen, and improving soil physical conditions.

The area occupied by grain legumes has fluctuated around 800 000 ha for the past 10 years, and the production from this area similarly around 600 000 metric tonnes. The low and variable yields obtained from these crops are to a large extent a result of the number and severity of the diseases that habitually affect them. These diseases affect both the yield and quality of the food legumes and constitute perhaps the most limiting factors to their production.

Diseases of Broad Bean (*Vicia faba*)

Broad beans are the dominant grain legume crop in North Africa, but yields are low and erratic as the commonly grown land varieties are poor yielders and susceptible to many pests and diseases. Fungal pathogens that affect the crop that may cause appreciable damage include *Botrytis fabae* (chocolate spot), *Uromyces fabae* (rust), *Cercospora fabae*, *Peronospora fabae* (downy mildew), *Fusarium culmorum* and *F. avenaceum* (root rot and wilt), and *Pleospora herbarum*. Of these, *Botrytis fabae* is by far the most important, becoming epidemic in hot and humid spring weather during flowering and fruit maturity and causing very great yield losses. Infection, for example, was so severe in 1970 and 1973 that farmers had no alternative but to plough in their crops. The disease is characterized by the appearance of circular brown spots on the leaves, from which it gets its common name, chocolate spot. These spots are usually from 1 to 3 mm in diameter, but can reach up to 15 mm and coalesce to form large necrotic areas in some cases. Diseased plants are also covered with necrotic lesions at their base and on their stems, and the flower parts and pods become covered in small black spots, which may result in a high percentage of flower sterility.

Although the other diseases are endemic to North Africa and appear regularly on the crop, they appear to have little economic importance in the region.

Diseases of Chick-pea (*Cicer arietinum*)

Chick-pea is the second-most important grain legume crop in North Africa and is grown on approximately half the acreage devoted to broad beans. Several pathogens affect the crop causing considerable yield losses. These include *Ascochyta rabiei* (blight) (also recorded as *Mycosphaerella rabiei*), *Fusarium oxysporum* (wilt), and *Pleospora herbarum*.

Perhaps the most severe of these diseases in the region is *Ascochyta* blight, which causes elongated cankers on the stems, and circular/oval, brown to white spots with red margins about 8–10 mm in diameter on the young leaves. The pods are also infected and the pathogen enters the seed in which it is preserved to cause future infections. Mild attacks of this disease usually cause losses of the order of 40%, but plants infected early in the season, or in humid springs when the disease takes on epidemic proportions, may lose all their green tissues and have to be ploughed in.

All land varieties grown in Tunisia are susceptible to *A. rabiei*, and, as the fungus can be preserved in very hardy structures on plant parts left in the soil as well as in the seed, it recurs regularly every year in the chick-pea crops, becoming very severe only when environmental conditions are favourable. Seeds with coloured seed coats have been shown to be tolerant to the pathogen, but are unfortunately of no commercial value.

In contrast to *Ascochyta* blight, the yellowing and wilting of plants caused by species of the genus *Fusarium (F. oxysporum* and *F. lateritium*) are particularly serious in dry seasons. Losses resulting from these pathogens, which are also preserved both in the seed and in diseased plant parts in the field, have been recorded as between 20 and 40% in Tunisia during 1977.

Pleospora herbarum, which is predominantly seed transmitted, causes a decreased germination capacity in infected seeds. However, the economic impact of the pathogen is, at present, negligible.

Diseases of Dry Peas (*Pisum sativum*)

Although ranking third in importance after broad beans and chick-peas in the region as a whole, dry peas are more important in Morocco. The presence of several pathogenic agents, which include *Ascochyta* sp. (*A. pisi*, *A. Pinodella*, and *A. Pinodes*) and *F. oxysporum*, has been confirmed on this crop.

Of these, *Ascochyta* sp. are the group most frequently observed and most economically important. Variations in the size of the fruiting bodies (pycnidia), the spores, and in the symptoms caused allow an easy distinction between the three important species of the pathogen. *A. pisi* has spores measuring approximately 4.2 × 13.9 microns, and causes large pale-brown spots containing black pyncidia intermediate in size, on the leaves and pods. Some stem injury may also be apparent. Whereas the other two species cause darker leaf spots with purple margins, *A. pinodella* has small pycnidia and spores measuring 3.7 × 8.8 microns and mainly causes root rot, while *A. pinodes* attacks all the plant parts and has large fruiting bodies and spores measuring 4.5 × 12.3 microns. All three species can be seed transmitted as well as preserved on plant parts in the soil and yield losses from infection may be severe, especially in Morocco, which, as a result of the oceanic influence, has a higher April to June rainfall and humidity than the other two countries.

Wilting caused by *F. oxysporum* f. *pisi* and other *Fusarium* species is characterized by yellowing of the foliage and dwarfing and may result in severe plant injury and yield loss. The disease favours dry soil and high temperature conditions and generally appears in the field in isolated circular foci, which enlarge as the season progresses and may coalesce to cause extensive field infection in serious attacks.

Diseases of Dry Beans (*Phaseolus* spp.)

Dry beans are cultivated on only approximately 14 000 ha of land in North Africa and thus make little contribution to the agricultural economy of the region. Many pathogens have been reported as infecting this crop, among which *Colletotrichum lindemuthianum* f. sp. *phaseoli*, which causes anthracnose (characterized by yellowing and wilting symptoms), bean mosaic virus (BMV), and bacterial diseases are the most significant.

Diseases of Lentils (*Lens* sp.)

Few studies have been carried out on the disease problems of this crop to date; however, *Botrytis* sp. and *F. oxysporum* appear to be the most important pathogens.

Research Efforts

From the limited volume of work so far undertaken on legume diseases in the North African region, it appears that *Botrytis fabae* is the fungal pathogen of major importance in broad beans and *Ascochyta* spp. and *Fusarium* spp. cause the most problems in chick-pea and dry pea crops. Past research on diseases of grain legumes has been concentrated on studies of *A. rabiei*, and insufficient importance has been attached to these other disease problems. Present research aims to correct this imbalance by focusing on the estimation of losses caused by all three major legume diseases; the evolution of reliable inoculation techniques for these pathogens to promote good artificial infections for screening purposes; the identification of lines of broad bean and chick-pea resistant to the major diseases; the analysis of symptom expression for the evaluation of host reaction to diseases and the determination of tolerance as well as general field resistance; and the evaluation of cultural and chemical control methods as supplements to the main control program, which focuses on host plant resistance. In this way a greater understanding of the mechanisms involved in disease infection and development, leading to the establishment of integrated strategies for minimizing these severe constraints to production, can be achieved.

Food Legume Diseases in Ethiopia

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The most important food legume crops in Ethiopia are grown in the highland regions, at altitudes of between 2800 and 3000 m where annual rainfall varies from 950 to 1500 mm. These crops include chick-pea (*Cicer arietinum*), broad bean (*Vicia faba*), lentil (*Lens culinaris*), grasspea (*Lathyrus sativus*), and field pea (*Pisum sativum*). Of these, chick-pea is the most important, occupying 30% of the total pulse acreage. Other relatively newly introduced species, such as soybean (*Glycine max*), cowpea (*Vigna unguiculata*), lima bean (*Phaseolus lunatus*), and haricot bean (*Phaseolus vulgaris*), are also grown on a small scale and predominantly at the lower altitudes.

The pulse improvement program in Ethiopia is still in its infancy. However, the limited studies made to date on legume crops have indicated that diseases caused by several species of soil and foliar fungi, nematodes, viruses, and mycoplasma result in serious crop losses and are a severe constraint to the more widespread and intensive cultivation of food legumes in the country.

Important Diseases

As it is the most widely grown pulse crop, chick-pea has benefited from considerably more work on its disease problems than the other food legumes. Of the diseases that cause serious yield losses in chick-peas, the complex of wilt and root rot is the most significant. These diseases, caused by a group of pathogenic fungi that include *Fusarium oxysporum*, *Sclerotium rolfsii*, *Rhizoctonia bataticola*, and *R. solani*, may result in losses of up to 80% in farmers' fields and contribute significantly to the low yields usually obtained from this crop (630–790 kg/ha). Similar problems of wilt and root rot also beset lentils, broad beans, and field peas.

Both chick-pea and safflower may suffer considerable losses from infection by a species of *Melodogyne* (the root knot nematode) and rust (*Uromyces ciceri arietini*), and more recently blight (*Ascochyta rabiei*) has been found to cause great damage under certain conditions.

On lentils, anthracnose (*Colletotrichum destructivum*), rust *Uromyces fabae*), and blight (*Ascochyta lini*) are the most significant diseases, whereas chocolate spot (*Botrytis fabae*) and rust cause the greatest yield loss in broad beans. Yield reductions of up to 35% have been caused by attacks of powdery mildew (*Erysiphe polygoni*) on field peas, and haricot beans suffer mainly from rust, anthracnose, and bacterial blights. Full details of the diseases recorded throughout Ethiopia are given in Table 1.

Studies on seed-borne microflora involving bioassays have revealed 38 fungi, 1 virus, and 1 bacteria (*Bacillus subtilis*) associated with soybean seed, and 15 fungi together with *B. subtilis* in association with seeds of chick-pea. Tests have shown that many of these fungi are pathogenic and such seeds may thus provide an important source of primary inoculum for disease development in the country.

Control Measures

Seed dressings of Furaden, Polyram combi, and Folcidin, when used in combination with insecticides, have been found to increase chick-pea yields by an average of 14% as a

TABLE 1. List of important pulse diseases recorded from surveys made between 1976 and 1977.

Chick-pea	**Field peas**
Ascochyta rabaei	*Fusarium*
Fusarium oxysporum[a]	*Oidium* spp. (*E. polygoni*)[a]
Rhizoctonia solani[a]	*Ascochyta pisi*
Rhizoctonia bataticola[a]	*Septori pisi*
Sclerotium rolfsii[a]	*Cercospora* leaf spot
Uromyces cicer arietini	*Uromyces pisi*
Leveillula taurica	
Melodogyne spp.	**Haricot beans**
Stunt virus	*Xanthomonas phaseoli*[a]
Phyllody	*Pseudomonas phaseolicola*
	Virus complex
Lentils	*Uromyces phaseoli* var. *typica*
Ascochyta lini	*Colletotrichum lindemuthianum*
Rhizoctonia solani[a]	*Fusarium* wilt
Sclerotium rolfsii[a]	
Fusarium oxysporum	**Soybeans**
Stunt virus	*Pseudomonas glycinea*
Uromyces fabae	Soybean mosaic virus
Colletotrichum destructivum	Downy mildew
Powdery mildew	*Sclerotinia sclerotium*
	Diaporthe phaseolorum var. *sojae*
Broad beans	*Macrophonina phaseolina*
Botrytis fabae[a]	*Colletotrichum dematium* var. *truncatum*
Uromyces fabae[a]	*Sclerotium rolfsii*
Sclerotium rolfsii	
Rhizoctonia bataticola	**Green pea (rough pea)**
Root knot nematodes	Rust
Erysiphe polygoni	Root rot[a]
Colletotrichum lindemuthianum	
Viruses	**Cowpea**
	Bacterial blight[a]
	Virus
	Yellowing flecks

[a] Presently identified as the most important diseases.

result of control of pathogens causing both wilt and rot and the control of soil-living insect pests. Treatments with the fungicide Thiram together with the insecticide Aldrin have also resulted in considerable yield increases (about 69%) over untreated checks.

Fungicide sprays of Tridemorph and Dinocap have given adequate control of powdery mildew, but dusting with powdered sulfur or spraying with Karathane results in much better control.

Dusting with sulfur has also been found to be useful in controlling rust diseases, but the development of resistant varieties appears to be a more practical method of consistent control. In controlling anthracnose, spraying with copper or dithiocarbamate fungicides, using disease-free seed, and planting resistant varieties have proved very effective measures. The use of disease-free seed, resistant varieties, and seed treatment with organomercurial fungicides is recommended for control of bacterial blights.

Screening of chick-pea lines for resistance to wilt, root rot, and *Ascochyta* blight is under way and has so far yielded some indication of a correlation between seed coat colour and wilt/root rot resistance, black and red seeded lines, in general, being fairly resistant to these diseases and white seeded varieties being more susceptible. Because there is a definite consumer preference for light seeded types, the combination of resistance and high yield into light seeded varieties has been a focus of previous research work.

At present, nurseries of chick-pea material from ICRISAT and of lentil material from ICARDA planted and screened in Ethiopia are yielding some promising lines. However, much more rigorous screening must be undertaken in the future to fully evaluate these varieties. Other research work currently under way includes the evaluation of field pea lines for resistance to *Ascochyta* blight, powdery mildew, and root rot, and of haricot bean varieties for resistance to bacterial blight and viruses.

Studies of cultural practices have shown that date of planting and planting depth have a definite influence on wilt and root rot incidence and development and hence yield loss. Planting around the end of July has given significantly higher yields than when planting is delayed, and the percentage recovery of pathogenic fungi from plants was found to decrease with delay in planting. Investigations have also shown definite improvements in plant stand and seed yield to be associated with planting at a depth of 6 cm as opposed to higher (2 cm) or lower (11 cm and 15 cm) in the profile. This may be as a result of the seed being less exposed on the one hand to adverse weather conditions and on the other to the seed-rotting organisms. Losses from wilt/rot diseases may also be minimized by avoiding the planting of susceptible varieties on low-lying and wet fields.

Research Priorities

The present survey work on pulse diseases will be extended to provide adequate and up-to-date information on the important diseases and the level of losses that result from them across the country.

The collection of local germ plasm and its evaluation alongside introduced material will be continued in an effort to produce a number of high-yielding varieties resistant to the specifically important diseases that prevail in Ethiopia.

Studies on the effect of cultural practices and chemicals on disease incidence and severity will be expanded to complement the breeding and selection work and to evolve a wide range of individual and integrated control measures.

Seed inspection by the plant quarantine section of the Ministry of Agriculture will be strengthened and a seed health-testing centre needs to be established so that pathogens on imported seeds can be detected and eliminated before causing damage within the country.

These developments, it is hoped, will provide a good and solid base to pulse pathology work in Ethiopia. However, severe constraints, such as inadequate laboratory facilities, insufficient field equipment, and trained manpower, and poor access to scientific work and information generated outside the country, are at present combining to prevent the rapid evolution that is necessary within the legume improvement program as a whole. The reduction of these constraining factors will pave the way for the development of adequate, appropriate, and consistent disease control measures, which will in turn reduce limitations to more widespread and intensive production of these legume crops.

Diseases of Broad Beans (*Vicia faba*) in the Sudan

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Broad bean, or "ful masri" to use its Arabic name, is a popular food crop in the Sudan. The dry beans, cooked overnight on a low flame and served with sesame oil, salt, and pepper, constitute a very common dish for the masses throughout much of the country. Although the price has almost doubled in the past few years (now equalling 240 Sudanese pounds per tonne) consumption is steadily rising. This is a good sign because nutritionally broad bean is a good protein substitute for meat, which itself is rapidly becoming increasingly expensive.

In the north of Sudan, where suitable climatic conditions prevail, comparatively large areas are annually sown to broad beans. The acreage, however, fluctuates considerably depending on the farmers' preference for the crop as opposed to its main alternative, French beans, which in turn is determined by market prices. Average yields vary from 1200 kg/feddan (1 feddan = 1.0379 acres) under research conditions to about 600 kg/feddan in the farmers' fields. This difference and the large annual yield fluctuations experienced can be attributed in part to the considerable number of diseases that affect the crop. Some of the more important of these diseases are currently under investigation at the Hudeiba Research Station.

Viral Diseases

Broad Bean Mosaic Disease

This is a common disease, widespread in broad bean-growing areas and especially severe in late sown crops. Its causal organism, Sudanese broad bean mosaic virus (SBBMV), is considered to consist of two distinct virus particles, namely pea mosaic virus (PMV) and broad bean mottle virus (BBMV), which can be present separately or in combination. PMV is the most common component and appears to be responsible for most of the damage (Table 1). Both viruses produce similar symptoms (i.e., mottling and (or) vein clearing) and can be carried symptomless in the plant. Transmission of PMV is through insects, specifically aphids, as well as mechanically and in seeds as with BBMV. PMV transmission in broad bean seed has been found to be more frequent than that of either BBMV or the complex SBBMV.

Disease development is closely related to sowing date; incidence and final percentage infection increases steadily with delay in sowing. Artificial infection with a mixture of the two viruses under field conditions has been shown to significantly reduce the plant height, number of pods per plant, and seed weight of crops sown at the optimum date. This effect, however, was masked in late sown plants (Table 2). Neither application of nitrogen nor

TABLE 1. Effects of the individual components of SBBMV on the components of broad bean yield.

Treatment	No. pods/plant	Seed wt (*g*)
PMV	9.0	4.9
BBMV	17.5	13.2
SBBMV	17.7	15.7
Control (no disease)	28.5	23.4

TABLE 2. Effect of SBBMV on the components of broad bean yield and its variation with sowing date.

	1972–73				1973–74				1974–75			
	Mean no. pods/plant		Seed wt (*g*)		Mean no. pods/plant		Seed wt (*g*)		Mean no. pods/plant		Seed wt (*g*)	
Sowing date	I[a]	NI[a]	I	NI	I	NI	I	NI	I	NI	I	NI
7 Oct.	26.0	35.9	23.9	40.5	2.5	29.0	1.1	24.9	17.9	36.9	15.1	30.9
21 Oct.	25.6	36.3	22.9	36.7	1.4	23.5	1.1	19.1	16.9	26.4	14.4	23.7
4 Nov.	18.9	20.3	20.9	25.6	1.0	14.9	0.4	10.8	14.1	18.4	10.7	13.7
18 Nov.	11.4	11.9	8.5	10.2	0.4	7.6	0.1	2.7	7.8	6.7	4.9	3.7

[a] I = inoculated with SSBMV; NI = not inoculated.

spraying against the vector has had any effect on disease incidence. This indicates that the extent of seed transmission may be considerably greater than at present envisaged. At this time the only control measure that can be advocated involves sowing at the optimum time (the second half of October).

Phillody (Green Flower) Disease

This is a minor disease that has previously been attributed to the group of witches'-broom viral diseases. Extensive and detailed surveys have consistently shown the incidence to be low and insufficient to justify concern at present. No insect vector nor any indication of secondary spread is evident and all attempts to transmit the virus by insects on dodder or in seeds have proved unsuccessful. Disease incidence diminishes sharply with delayed sowing but so far no other consistent control method has been discovered.

Fungal Diseases

Powdery Mildew

This is one of the major fungal diseases in Sudan, causing considerable losses in years favourable for its development and spread. It is caused by *Leivellula taurica* Lev., which infects the crop early in the season, and *Erysiphe polygoni* and an *Oidium* species that appear later in the season. Disease incidence can be significantly reduced by applications of several fungicides, especially sulfur-based compounds, but this has not been found to be associated with a reduction in yield losses, even if used as a protective measure before the appearance of infection symptoms. However, losses can be greatly reduced by sowing at the optimum time (late October). All local and previously introduced varieties are susceptible to the disease and hence sources of resistance introduced from Russia and Germany are currently being used in breeding programs aimed at achieving better control.

Wilt and Root Rot Diseases

Since 1972, the incidence and severity of diseases causing a variety of wilting symptoms has increased considerably, especially in seasons with conditions of relatively high temperature. The variation in disease symptoms suggests the involvement of more than one pathogen, and this has been confirmed by the isolation from diseased material of *Fusarium oxysporum*, responsible for the typical wilt symptoms characterized by general leaf yellowing and discolouration of the xylem vessels, and *Fusarium solani* f.sp. *fabae*, causing the yellowing of the margins and gradual death of older leaves and the sudden death of younger leaves associated with basal rotting of the roots.

In addition to the negative effect on seed yield, which can be considerable, infection by these pathogens has been found to significantly reduce seed quality, especially protein content. Results of investigations into chemical control of these diseases have so far proved negative, and although there are significant differences between varieties in the degree of infection, no good source of resistance has yet been discovered. However, again, sowing date can be seen to positively affect disease development (Table 2) and losses due to these diseases may be minimized by late sowing.

Disease Complex

This is a newly recorded disease, causing necrosis of stems, leaves, and pods, basal root rotting, and the rapid collapse of plants. Isolation tests suggest that the disease is caused by a combined infection of *Fusarium* spp. and *Helminthosporium spiciferum*. It is aggravated by water stress and high temperatures but severity can be to some extent reduced by avoiding early sowing of the crop.

Diseases of broad beans in the Sudan cause considerable loss almost every year. However, losses vary with environmental conditions and can be minimized by choosing the optimum sowing date when only one disease prevails or a compromised sowing date where more than one disease is important. At present, control through chemicals and varietal resistance has proved largely ineffective in reducing disease losses. Nevertheless work continues in the development of effective control methods aimed at giving a much greater and more stable production of this crop, which is so important to the life of Sudan.

Section IV

Major Pests and Weeds of Food Legumes

Insect Pests of Food Legumes in the Middle East

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Food legumes are attacked by a variety of insect and mite pests that feed on the leaves, the seeds in their pods, or on the underground parts of the plants. A key of the most important insect and mite pests of beans, peas, chick-peas, and lentils grown in Middle Eastern countries is as follows.

Key to the most important insect and mite pests of beans, peas, chick-peas, and lentils in the Middle East

A. *Insects and mites sucking sap from the leaves and stems*

(1) Small, greenish, long-legged aphids feeding on undersides of leaves and stems and causing plants to look bronzy and wither .... *Macrosiphum pisi*

(2) Black aphids found on the terminal growth of beans; plants often become covered with sooty mould .... *Aphis fabae*

(3) Bean leaves become yellow or bronzed in colour and die; white webs on underside of leaves, among which are many microscopic eight-legged reddish or greenish mites .... *Tetranychus urticae*

B. *Insects eating holes in the leaves or tunneling in stems*

(1) A tiny weevil with a striped body that feeds by eating crescent-shaped pieces from the margins of leaves .... *Sitona lineata*

(2) Wilted bean plants and dead stems with tiny white maggots inside .... *Melanagronyza phaseoli*

C. *Insects attacking seeds within the pods in the field and in storage*

(1) Peas within pods partly eaten by cream-coloured caterpillars (up to 13 mm long) covered by webs and surrounded by pellets of excrement .... *Laspeyresia nigricana*

(2) Chick-pea pods containing large greenish caterpillars with alternating light and dark stripes along the length of the body .... *Heliothis armigera*

(3) Interior of peas in the field and in storage eaten by tiny white grubs and brownish beetles with two small black spots at tip of abdomen; only one insect in each seed ...... *Bruchus pisorum*

(4) Interior of beans and peas in the field and in storage eaten by grubs similar to C3 and by smaller brownish beetles; often several insects in a seed .... *Bruchus rufimanus*

D. *Insects cutting off plants near the surface of ground or feeding on underground parts*

(1) Plants chewed off near surface of ground by brown, gray, black, or dull-green greasy-looking and variously striped or spotted caterpillars .... *Cutworms*

(2) Seedlings uprooted and roots cut off by a weird-looking brown cricket with strong digging shovel-like front legs .... *Gryllotalpa gryllotalpa*

Pea Aphid

The pea aphid, *Macrosiphum pisi* (Harris), belongs to the family Aphididae of the order Homoptera. The adult aphid is long-legged and green in colour, and the largest individual measures about 5 mm long. It has red eyes, and its legs and cornicles are usually tipped with yellow. Winged and wingless forms are found together on the plants.

Host Plants

Peas, sweet peas, clover, sweet clover, alfalfa, and weeds of the legume family are commonly attacked by the pea aphid.

Damage

Infested plants wilt as a result of the sap sucking of the aphids and bronzy patches appear in the field. The pea aphid is also a vector of pea enation mosaic virus, which infects peas, vetch, and sweet clover, and of the yellow bean mosaic of peas and alfalfa.

Life Cycle

M. pisi may continue to breed during the winter in areas where host plants are available and climatic conditions are favourable for its development. In spring, the aphid population increases sharply and several generations are produced during the spring and summer months. Winged forms appear when the aphids become crowded on the plant and these spread to other plants to start new colonies. In areas where the temperature in autumn drops and winters are cold, the pea aphid follows a holocyclic life pattern. In autumn the viviparous females give birth to young aphids, some of which develop into winged males and others into winged and wingless females. These become sexually mature, copulate, and the females lay their eggs on the leaves and stems of alfalfa and red clover. The eggs are light green in colour at first and gradually change to shiny black; after overwintering they hatch into wingless parthenogenetic stem-mothers in the following spring.

Control Measures

A number of systemic organophosphate insecticides are effective against the pea aphid. In recent years, several aphicides have been developed; these have the added advantage over broad-spectrum insecticides of specificity of action against aphids alone.

Bean Aphid

The bean aphid *Aphis fabae* (Scop.) also belongs to the family Aphididae of the order Homoptera. The adult aphid is black in colour and smaller in size than the pea aphid. Winged and wingless forms are found together on plants.

Host Plants

Bean plants are the main host of *A. fabae*. Many weeds are also infested by this aphid.

Damage

The aphids are found mainly on the terminal growth of plants where they suck the sap and cause yellowing of leaves and dwarfing of plants. Black sooty mould develops on the leaves as a result of the secretion of sugary substances by the aphids. *A. fabae* is also a vector of bean common mosaic, yellow mosaic, and soybean mosaic viruses.

Life Cycle

It is very common to find bean aphids on plants all the year round in areas where climatic conditions are favourable for their development. Under such conditions they continue to reproduce parthenogenetically, producing many generations per year. However, in colder areas sexual forms appear late in autumn and the eggs are laid on woody plants. The eggs hatch as soon as weather conditions become favourable and parthenogenetic reproduction is resumed.

Control Measures

These are similar to the measures used for the control of pea aphids.

Spider Mites

Spider mites belong to the family Tetranychidae of the order Acarina, class Arachnida. They are cosmopolitan in distribution and infest a wide variety of plants. Many species exist, of which the two-spotted spider mite *Tetranychus urticae* (Koch) is the most common and widely distributed. The adult female mite is about 0.5 mm long and many range in colour from pale green to brown and orange. The male is smaller, about 0.35 mm long, with a narrower body and pointed abdomen. The body is oval in shape, nonsegmented, and covered with spines. The two dark spots that give the mite its name are readily visible on the back. The larval stage has three pairs of legs, and subsequent stages have four pairs. The egg is spherical and pearly white in colour at first, changing to yellowish orange with embryonic development.

Host Plants

T. urticae is a highly polyphagous mite and attacks a wide variety of crops including beans, squash, eggplants, tomatoes, apples, and many ornamental plants and weeds.

Damage

The leaves of plants infested with two-spotted spider mite turn brown due to the suckling of the mites, gradually die, and are shed. The female mites spin webs on the undersides of leaves within which they lay their eggs. In heavily infested plants, mites are readily seen moving about in the web.

Life Cycle

Only the fertilized females of *T. urticae* overwinter in protected locations, usually on trees, the males having died immediately following copulation. In spring, the mites at first infest the weeds and then migrate to vegetables and fruit trees. The egg hatches into the larval stage, which has only three pairs of legs. The larva then passes through a resting stage known as the nymphochrysalis and emerges as the protonymph with four pairs of legs. Again it passes through a resting stage, the deutochrysalis, and into the second active stage, the deutonymph. A third resting stage, known as the teleiochrysalis, follows, which culminates in the adult stage. The adult male and female copulate shortly after emerging and the female starts to lay eggs 2 days later. The larvae reach the adult stage in 6 days at 22 °C and in 32 days at 10 °C. Therefore, several generations may be produced per year, and it is very common to see all stages of development on one plant.

Control Measures

The indiscriminate use of broad spectrum insecticides like DDT, which had no effect on mites and killed only their natural enemies, has resulted in a tremendous increase in mite populations. At present, mites are the most serious pest on many crops all over the world. They have acquired resistance to many commonly used pesticides and new chemicals have to be developed constantly to keep abreast of the mite problem. Several specific acaricides are available on the market at present. In a study on the control of the two-spotted spider mite on apples, two acaricides proved to be very effective: they were Plictran, tricyclohexyltin hydroxide and Phosalone, a phosphorodithioate compound.

Pea Leaf Weevil

The pea leaf weevil *Sitona lineata* (L.) belongs to the family Curculionidae of the order Coleoptera. The adult is a beetle measuring 4–5 mm long, dark in colour, and covered with a dense coat of short hairs. Dark- and light-coloured rows of hairs on the back of the beetle give it a striped appearance. The larvae are legless, whitish in colour, and bear brownish hairs on their bodies. The egg is oval in shape, yellowish white in colour when first laid, and darkens in colour as embryonic development proceeds.

Host Plants

The pea leaf weevil attacks many leguminous plants, including peas, beans, alfalfa, and clover.

Damage

The adult beetles feed on the host plants by chewing small crescent-shaped areas from the leaves. The larvae feed on the nitrogen-fixing bacterial nodules and on the roots. Damage by this insect is most serious in newly emerged seedlings, as the feeding of the beetles results in total destruction of the young leaves.

Life Cycle

S. lineata passes the winter in the adult stage. In early spring, when the temperature reaches about 15 °C, the adults start to appear and feed on the host plants. Copulation takes place in about 2 weeks, and the females lay their eggs on the soil below the plants. The incubation period of the eggs is considerably influenced by humidity and temperature. High relative humidity is very important for embryonic development. The newly hatched larvae crawl into the soil and feed on the nodules and the roots. The larval stage is completed in 3–4 weeks and pupation takes place in the soil, requiring 10–15 days for completion. Adults of the new generation start to appear in mid-July but most emerge in August and September.

Control Measures

The adult beetles should be controlled as soon as they appear on the young seedlings. Many of the contact organophosphorus insecticides are effective against this insect.

Bean Fly

The bean fly *Malanagromyza phaseoli* (Cog.) belongs to the family Agromyzidae of the order Diptera. The adult fly is blackish in colour with red eyes and measures about 2.5 mm long. The larvae are cream white in colour and reach a maximum length of 4 mm. The egg is pearly white and oval shaped.

Host Plants

Bean, soybeans, and a variety of weeds are the hosts of this fly.

Damage

The larva feeds by mining through the leaf and the petiole; it reaches the stem where it continues moving downward. Feeding of the larva introduces rot-causing microorganisms into the plant and these cause breakdown of tissues and consequent wilting of the plants.

Life Cycle

M. phaseoli has several generations per year. The time required to complete one generation depends on temperature and ranges from 12 days in summer to 19–26 days in autumn. The adult lays its eggs in the tissues of the upper surface of bean leaves. The newly hatched larvae tunnel in the leaves and into the stem where they continue feeding until they reach full size. Several larvae usually pupate together in the stem. Attack by this insect is almost continuous on beans grown in the autumn.

Control Measures

Chemical control of *M. phaseoli* is difficult to achieve as the larvae feed inside the plants. Soil treatment at planting time with granular systemic insecticides, such as carbofuran, followed by foliar sprays with systemic insecticides, have proved effective in preventing early damage to plants.

Pea Moth

The pea moth *Laspeyresia nigricana* (Stephens) belongs to the family Olethreutidae of the order Lepidoptera. The adult is a small and delicate moth measuring about 15 mm across the spread wings. The moths, which are brown in colour with short black and white oblique lines along the front margin of the first pair of wings, are usually seen flying about the plants in late afternoon. The larva is yellowish white in colour and measures about 13 mm long. It has small dark spots and short hairs scattered over the body. The egg is white, flattened, and minute.

Host Plants

The pea moth attacks field and garden peas, sweet peas, and vetches.

Damage

The caterpillars attack the seeds inside the pods and their presence is not easily detected unless the pods are opened. The seeds are spoiled and the pods partially filled with excreta and the silken webs of the caterpillars. Often fungus may develop and spoil seeds that are not damaged by the worms.

Life Cycle

L. nigricana overwinters in the larval stage inside silken cocoons. These are usually found in the soil a short distance below the surface. In late spring the larvae pupate and the adults appear as the peas start to blossom. Eggs are laid on the plants, and as soon as the tiny larvae emerge they eat their way into the pods without leaving noticeable holes. They stay in the pods until they become full grown, when they emerge to drop into the soil. There is usually only one generation per year.

Control Measures

Chemical control of this insect is difficult, as all the caterpillars do not emerge from the eggs at the same time and they are protected inside the pods. Therefore, control measures should concentrate on the removal of crop remnants from the field, deep plowing in autumn to kill overwintering larvae, and planting of early maturing varieties.

Corn Earworm

The corn earworm *Heliothis armigera* (Hb.) is also known as the tobacco budworm, tomato fruitworm, cotton bollworm, and vetchworm. It belongs to the family Noctuidae of the order Lepidoptera. The adult moth has a wingspan of about 40 mm, the front wings being light grayish brown with dark-gray irregular lines and with dark areas near their tips, while the hind wings are white with dark bands around the margins. The caterpillars vary in colour from light green to brown or black and are marked with alternating longitudinal light and dark stripes. The head is yellow and the legs are dark or nearly black. A full-grown caterpillar reaches 40 mm long. The egg is hemispherical and longitudinally striped.

Host Plants

The corn earworm is a highly polyphagous pest attacking a wide variety of crops and weeds. It is most serious on corn, tomato, tobacco, cotton, and vetch. It also attacks chick-peas but infestations are not normally serious. In a study conducted in the Beka'a (Lebanon), it was found that chick-peas planted in May and June were almost free of damage whereas those planted in March and April had about 6% infested pods.

Damage

The caterpillars feed on the fruits of infested plants and render them unmarketable.

Life Cycle

H. armigera overwinters in the pupal stage in the soil. The moths appear between mid- and late April, depending on weather conditions, and copulation starts shortly afterward. The females lay their eggs on host plants and the young caterpillars feed briefly on the leaves before boring into the fruits. In about 20–25 days, the larvae become full grown, leave the fruits, and drop to the soil to pupate. New moths appear in about 15 days and the insect thus has several generations per year.

Control Measures

Chemical control of the caterpillars is vital especially on crops that are heavily attacked by this pest. A variety of contact organophosphate and carbamate insecticides may be used and early treatment is important.

Pea Weevil

The pea weevil *Bruchus pisorum* (Linne) belongs to the family *Bruchidae* of the order Coleoptera. The adult is a short oval-shaped beetle, about 4 mm long, brownish in colour with white and black patches and two small black spots at the tip of the abdomen. The larva is tiny, whitish to yellowish in colour, with a brown head. It has very short legs and spines on the body that help it in burrowing in the pod and seeds. The eggs are elongate and yellowish in colour.

Host Plants

Peas are the only plants attacked.

Damage

This insect feeds inside pea seeds in storage and renders them unfit for human or animal consumption. Green peas are also attacked, and infested seeds lose their viability, failing to produce a good stand when planted.

Life Cycle

B. pisorum overwinters in the adult stage either in stored peas or in crop remnants in the field. The weevils emerge when the plants are in blossom, feed on various parts of the plant, and the females lay their eggs on the pods. The eggs hatch in about a week, and the tiny larva eat their way through the pod and into the seeds. Only one insect develops in each seed. The larva continues to feed inside the seed until it becomes full grown and pupates inside a gluey substance that it secretes. There is only one generation per year. The weevils do not reproduce in stored peas, as the female can only lay her eggs on growing plants.

Control Measures

Field infestations may be controlled with contact organophosphate insecticides applied to the plants during the early bloom period before the eggs are laid. Removal of plant remnants by plowing under or burning is very effective in controlling the overwintering weevils. Fumigation is used to control the insects infesting stored peas; camphor gave 100% mortality in the weevils when applied as a fumigant in airtight containers at concentrations of 12, 24, 48, and 96 ppm.

Broad Bean Weevil

The broad bean weevil *Bruchus rufimanus* (Boheman) also belongs to the family Bruchidae of the order Coleoptera. The adult is similar to the pea weevil except that it is smaller in size and lacks the two black spots at the tip of the abdomen so conspicuous in the pea weevil. Furthermore, the tooth near the apex of the femur is broader and more blunt than in the pea weevil.

Host Plants

Broad beans are the preferred host of this insect, but it also attacks peas and vetches.

Damage

Like the pea weevil, this insect continues its feeding inside stored seeds and renders them unfit for human or animal consumption.

Life Cycle

B. rufimanus resembles the pea weevil in its habits and development. The only striking difference is that several insects infest a single seed in contrast to the pea weevil, where only one insect is found per seed.

Control Measures

These are similar to the measures used for controlling pea weevils.

Cutworms

Cutworms include many species of the family Noctuidae, order Lepidoptera. An example is the greasy cutworm *Agrotis ypsilon* (Hufn.). The adult is a moth with narrow gray-brown front wings and hind wings that are pearly white in colour with dark veins and margins. It measures about 48 mm across the spread wings. The caterpillar is grayish in colour, greasy, and almost hairless except for some very short spines. When full grown, the caterpillar measures about 40–45 mm long. The egg is round and ribbed, white in colour at first, but changing to yellow with embryonic development.

Host Plants

Cutworms are highly polyphagous and attack a wide variety of plants including vegetables, cotton, corn, tobacco, and clover.

Damage

Cutworms injure plants in several different ways; certain species kill the plant by cutting off the stems at the crown or at a short distance below the surface of the soil, moving about and damaging several plants at a time; other species remain in the soil and feed mainly on the roots, and still others (the climbing type) crawl on plants and feed on the leaves, fruits, and buds.

The caterpillars of *A. ypsilon* feed on the leaves of plants when they are young, but as they grow, they move to the soil and feed on stems, cutting them off and killing the plants.

Life Cycle

A. ypsilon overwinters in the soil either in the larval or pupal stage. In spring, the moths start to appear, and after a short period, the females lay their eggs on the leaves of host plants. The caterpillars emerge in 3–12 days, depending on weather conditions, and feed on the host plant until they become full grown, after which they pupate in the soil. One generation needs anywhere from 5 to 10 weeks to be completed, and thus several generations are produced per year.

Control Measures

Controlling cutworms, especially those that remain constantly in the soil, is not very easy. Furthermore, cyclodicides, which are effective against cutworms, are no longer recommended for use due to their long persistance. Soil-applied insecticides of the carbamate group are used at present in applications, either at planting time or shortly after seed germination.

Mole Cricket

The mole cricket *Gryllotalpa gryllotalpa* (L.) belongs to the family Gryllotalpidae of the order Orthoptera. The adult is a weird-looking dark-brownish insect about 45–50 mm long. It has short semimembranous wings and a pair of long and jointed cerci extending from the tip of the abdomen. Its first pair of legs are short, stout, flattened, and specially adapted for digging. The egg is ovoid and white in colour.

Host Plants

Mole crickets attack a wide variety of crops including legumes, crucifers, potato, corn, tobacco, and cotton.

Damage

Mole crickets are especially damaging to seedlings and young plants. The insect lives in the soil killing the plants by feeding on the roots and underground parts. Its presence can be easily noticed by the zig-zag cracks it leaves in the soil as it moves just below the surface. The insect feeds on several plants at a time and thus can cause extensive damage. It is specially abundant in soils rich with animal manure.

Life Cycle

G. gryllotalpa overwinters in the nymphal or adult stages in the soil. In spring, it resumes its activity and development. After copulation, the female lays its eggs in a special chamber formed in the soil. Shortly after emerging, the nymphs start feeding on plants and causing damage, which increases as the insect grows older.

Control Measures

The best method of controlling mole crickets is by the use of poison baits applied to the soil where the zig-zag cracks are visible. As the insect feeds at night, the bait should be spread early in the evening, preferably after irrigation. The bait consists of an insecticide mixed with wheat bran and small quantities of molasses and water. BHC, chlordane, and carbaryl are equally effective against this insect. However, carbaryl is preferred to the other two because it is less persistent in the environment. In a study on the control of mole crickets infecting corn, BHC containing 2.6% of the gamma isomer and 5% Carbaryl dust each mixed with wheat bran in the ratio of 1:5 and 50% WP Chlordane at the ratio of 1:20 has proved very effective in controlling these crickets when applied a few days after planting. In heavily infested areas a second treatment, applied 10 days later, is required.

Insect Pests of Chick-pea and Lentils in the Countries of the Eastern Mediterranean: A Review

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This review covers the major insect pests of chick-pea (*Cicer arietinum*) and lentil (*Lens culinaris*) found in Cyprus, Iran, Iraq, Jordan, Lebanon, Syria, and Turkey. In these countries, lentils and chick-peas are grown under rainfed or partly irrigated regimes and form an important part of agricultural production. Both crops are attacked in the field and in store by a large number of insects. Some of these pests are considered to be present regularly, whereas others are sporadic in occurrence. Few are regarded as important agricultural pests, although damage may be severe in some cases.

Aphids
(Order Hemiptera; suborder Homoptera; family Aphididae)

Aphid species are generally of lesser importance in the eastern Mediterranean than in Europe and are rarely considered to be major pests of either lentil or chick-pea. Damage results from the insects sucking plant sap from the leaves, stems, flowers, and pods, feeding from the flowers and pods causing the greatest injury. In addition to this direct damage, further injury may be caused both by the honeydew secretion of the insects, which may interfere with photosynthesis and pollination, and the aphids' virus transmission capabilities.

Aphis craccivora and *Acyrthosiphon pisum* are the two species of economic importance attacking lentil and chick-pea respectively. They are cosmopolitan in distribution and whereas *A. craccivora* infests several widely differing plant genera, *A. pisum* is restricted to leguminous plants. Aphid infestations in the region normally occur between late April and May and can cause severe problems of virus infection in the attacked plants.

A survey carried out in Iran has shown that almost all the viruses infecting leguminous crops are aphid transmitted, *A. craccivora* and *A. pisum* figuring among the major vectors. These aphids, together with *A. sesbaniae*, have been shown to be the major aphid vectors of alfalfa mosaic virus (AMV), bean yellow mosaic virus (BYMV), cucumber mosaic virus (CMV), and pea leaf roll virus (PLRV), all of which cause considerable damage to legume crops. In Australia, *A. craccivora* has also been found to transmit subterranean clover stunt virus; and a similar virus causing stunting of chick-peas in India has also been transmitted by this insect in laboratory tests.

The control of aphids through the use of chemicals appears at present to be largely uneconomic, and thus the development of virus-resistant lines of chick-pea and lentil seems to afford the best means of minimizing plant injury and yield loss. In addition to these methods, biological control mechanisms may also be evolved using such parasitic and predatory insects as *Trioxys angelica*; *Lysiphlebus fabarum* and other *Lysiphlebus* spp. (parasitic wasps); *Coccinella 7-punctata* L. and *Adalia* spp. (*ladybirds*); and *Adonia variegata*, all of which have been found attacking aphid species.

Moths

(Order Lepidoptera; suborder Ditrysia; family Noctuidae)

The insects of this family are considered to be the most damaging pests of field crops in the eastern Mediterranean. They are polyphagous (capable of raising several generations per year), and some species even migrate between countries in the region.

Lentils and chick-peas are infested by several species of this important family, the most significant of these being; the lesser army worm (*Spodoptera exigua*); the winter cutworm (*Agrotis segetum*) and the black cutworm (*A. ipsilon*); the chick-pea podworm (*Heliothis armigera*) and other *Heliothis* spp., such as *H. peltigera*, *H. nubigera*, and *H. viriplaca*; the watermelon looper (*Trichoplusia ni*); and the silvery moth (*Plusia gamma*). Of these, the chickpea podworm, the cutworms, and the lesser armyworm are the most important and regular pests.

The chick-pea podworm (*Heliothis armigera*) is an old world species and is variously also called the African or American cotton bollworm or the tomato fruitworm, depending upon its location and host plants. The economic damage is caused exclusively by the larvae, which when young feed on the flowers and in the later stages of their growth on the developing fruits. Chick-peas, beans, and peas are affected as well as a wide range of other crops including cotton, tobacco, tomato, green pepper, maize, sorghum, and groundnut. The appearance of adult moths in the crop depends largely upon the climate and geographic location of the country concerned, which govern the emergence of the adults from the pupal phase in the soil. Adults are usually observed from April onward but in mild winters they have been seen as early as the end of February. This is the case in Syria, Northern Iran, Northern Iraq, Turkey, and Eastern Europe where the insect overwinters in the pupal stage, but in other areas, where the insect passes the winter as an adult, emergence varies considerably.

In West Bengal, where *H. armigera* is a serious pest of chick-pea, it has been found that the degree of infestation and resultant yield loss increases proportionately to the delay in sowing. This is mainly because early sown crops are past the critical flowering stage, to which infestation is largely restricted, by the time the adult moths have appeared. In support of this it has been shown that lines of chick-pea resistant to frost and drought, and thus able to be sown earlier than normal varieties, have proven significantly less susceptible to attacks of *H. armigera*. In view of the short period during which oviposition takes place, it has been suggested that inseminated females are attracted to the flowers by suitable physiological cues. The identification of these cues could assist in the breeding of resistant varieties.

Other species of *Heliothis* have also been observed infesting chick-pea plants in the region. These include *H. peltigera*, which attacks several crops in Iraq.

Of the cutworms, *Agrotis ipsilon* is a cosmopolitan species, whereas *A. segetum* is confined to the old world. Both are voracious feeders on a wide range of cultivated and wild plants, but *A. ipsilon* is considered to be the most injurious to crop plants. Although all the larvae cause injury to plants, the last instar larvae result in the most significant damage, as they live in the soil and attack the plants at their crowns, cutting them off completely. One larva may destroy a large number of plants in this way.

A. ipsilon causes considerable crop injury in the autumn and spring months, but is usually scarce in the summer, having generally only three to four generations per year. However, in Syria and Lebanon the insect may have as many as six generations and can thus cause appreciably more damage. *A. ipsilon* attacks a number of cereal crops, but within the Leguminoseae is primarily a pest of lentils. *A. segetum* is also a pest of both winter and summer crops, having from three to four generations per year and causing serious damage to maize and cotton as well as to chick-peas.

Spodoptera exigua, the lesser armyworm, is both cosmopolitan and polyphagous, feeding as it does on a wide range of crop plants that include the grasses, legumes, cotton, beet, and potato. It is one of the major pests of field crops in the Eastern Mediterranean region.

The number of generations raised per year varies with location but has been estimated as five in Syria and six in the Karaj area of Iran. The second and third generations are probably the most damaging, starting in May and continuing through until June or July. The larvae rest in the soil during the day and at night feed on the plant leaves; the young larvae destroy the leaf laminae, leaving a fine network of veins, whereas the older ones consume the whole leaves. In a serious attack, the larvae move in large masses (hence the name "armyworm") and may destroy all the vegetation in a field.

Several other Noctuid pests also cause economic damage under certain conditions. The pyralid legume pod moth (*Etiella zinckenella*) is an insect cosmopolitan in distribution, but confined to leguminous plants in its host range. The larvae feed upon the soft seeds in the pods, and in the case of small seeds a single larva may consume several pods. In one study in the Punjab area of India, 12–15% of lentil pods were found to be infested by this pest.

P. gamma and *T. ni* are both polyphagous insects feeding on a range of hosts, among which chick-peas and lentils are particularly important. The damage is caused by the larvae, which feed upon the leaves of the host and may be severe in some years, especially in the spring months.

Weevils

(Order Coleoptera; suborder Polyphaga; family Cucujoidea)

In the eastern Mediterranean countries leguminous plants are infested by many species of the genus *Sitona*. The most common and economically important members of this group include *S. lividepes*, *S. hispidulus*, S. crinitus, *S. lineatus*, and *S. limosus*.

In general, in the Mediterranean area, adults of *Sitona* aestivate in the soil during the summer, and the termination of diapause takes place in the winter, in contrast to their behaviour in colder climates, where the adults hibernate over the winter and become active in the summer months. Thus, in eastern Turkey, *S. crinitus* resumes its activity in April, whereas in the southern Mediterranean it becomes active in November–December. In all areas the insect only has one generation per year. The adults cause damage, especially to young plants, as a result of their feeding on the leaves and the larvae also injure the plants by attacking the root nodules.

S. crinitus has been recorded feeding on lentil, chick-pea, and vetch in northeast Syria and, in addition to these, on lucerne in Turkey. It is perhaps one of the most significant weevil pests attacking legume crops. *S. lineatus* is, however, the single-most important leguminous weevil pest, attacking peas, broad beans, and vetches voraciously. Feeding tests have shown that in the absence of legumes this insect will attack a large number of other plants, mostly of the Rosidae and the Hammelidae, but that if legumes are present it will feed exclusively upon them.

In addition to the *Sitona* weevils, *Hypera postica* (the alfalfa weevil) has also been observed infesting lentils in Syria, and *Apion* spp., such as *A. arrogans*, *A. aestivum*, and *A. seniculus*, have been recorded feeding on the ovules, buds, and young seeds of vetch, broad bean, alfalfa, and clover in countries of the southeastern Mediterranean.

Seed Beetles

(Order Coleoptera; suborder Polyphaga; family Bruchidae)

Bruchid beetles attack legume seeds almost exclusively and many species are serious pests of stored lentils and chick-peas. The most important species found in the east Mediterranean include: *Bruchus ervi, B. lentis, B. emarginatus, B. signaticornis, B. pisorum, Callosobruchus chinensis, C. maculatus, C. analis, Acanthoscelides obtectus,* and *Spermophagous sericeus*.

Of these pests, *B. lentis*, *B. ervi*, and *B. signaticornis* may cause infestations of up to 80% of lentil seeds in Syria, Turkey, Iran, and other neighbouring countries. These species raise only one generation per year. Infestations start in the field, but larval development, pupation, and adult emergence take place in the stored seed, the females being incapable of laying eggs on dry seed.

Other seed beetles of the genus *Callosobruchus* raise several generations per year and can thus be considerably more destructive. *C. chinesis* and *C. maculatus*, for example, have six and eight generations per year, respectively, and cause very heavy infestations of lentil and chick-pea seeds.

It has been found that rearing of *C. maculatus* at low temperatures (15–18 °C) resulted in fewer eggs and a steady decline in insect population over time, with no noticeable acclimatization. This points the way for the development of practical control measures along these lines. Studies on the resistance of chick-peas to attack by seed beetles has shown that varieties with rough-textured or spiny seed coats appear to act as deterrants to oviposition by species of *Callosobruchus* and are thus less heavily attacked than smooth-coated varieties. It has also been found that, due to the presence of a heat labile-trypsin inhibitor and a dietary deficiency of cholesterol, lentil is an unsuitable host for the knapra beetle, *Trogoderma granarium*. Further studies of this resistance might also be profitable in controlling damage by other seed beetle species.

Agromyzid Flies

(Order Diptera; suborder Cyclorrhapha; family Agromyzidae)

The tiny larvae of these flies mine through the leaves of leguminous plants, feeding on the mesophyll and leaving transparent trails. Chick-peas are infested principally by *Liriomyza cicerina*, and severe damage may be caused when the density of the larvae exceeds 50 per plant. The life history of this insect was studied near Izmir in Turkey and it was discovered to have two generations per year and to overwinter in the pupal stage. Upon emergence in late April, the female deposits her eggs in the leaf tissue, laying one in each puncture and one to three eggs in each leaf. The larvae mine throughout the leaves and then pupate in the soil. In Syria some larvae have also been found to pupate inside the gallery and this indicates that infestations are also caused by larvae of the species *Phytomyza atricornis*.

Some Insect Pests of Leguminous Crops in Syria

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Preliminary observations on the infestation of legume crops by various insect pests at the ICARDA site at Tel Hadia near Aleppo in northern Syria over the bulk of the 1978 growing season (February to April 1978) has enabled the following partial list of insect pests of economic importance to legumes in the area to be drawn up. This list is of necessity incomplete, but future observations and investigations over several growing seasons will enable a more exhaustive tabulation to be completed.

Leaf Weevils (*Sitona* spp.)

Adults of *Sitona* sp. have been observed infesting lentils and broad beans from the first week of February. Percentages of infestation varied between plots from 12 to 62%.

Preliminary results of tests on 544 entries of lentils indicate no correlation between infestation and leaflet size or plant variety. There also appears to be little, if any, relation between date of planting, plant spacing, or crop density and percentage of infestation.

Leaf Midges (*Contarina* spp.)

Damage symptoms, resulting from larvae attacking the upper leaves, were observed during the first week of March on lentils, broad beans, and other *Vicia* species. Approximate percentages of infestation, calculated on the 1–5 grading system, varied from 10 to 40% in lentils to 80–90% in broad beans. In the latter case infestation was particularly high in late-sown varieties due to the emergence peak of the insect's second generation coinciding with the crop's young and more susceptible stage. Damage up to 80% was also observed on *Vicia narbonensis*, a forage legume.

Leaf Miners (*Phytomyza* spp.)

The larvae of this insect were observed mining through the leaves of pea plants in mid-March. Percentages of infestation varied from 15 to 30% upon the emergence of the second generation insects. Mining by another *Agromyzid* species was observed on chick-peas, causing leaf damage of up to 50%.

Seed Weevils (*Apion* spp.)

Damage became obvious in mid-March and adults of the species could be seen on the leaves of lentils, while the larvae infested the floral parts. Infestations recorded varied from 10 to 75%.

Aphids

Aphids were first observed on broad beans, lentils, peas, and medics in the second half of March, and thereafter the population built up continuously, as many as 300 insects per plant being recorded.

Pod Borers (*Heliothis* spp.)

Adult moths were evident in the field by the end of March, but larvae boring into the chick-pea pods were not observed until the second week of April. Larval counts of up to 50 per mm^2 were recorded, and infestation ranged from 4 to 21%. Varietal differences in the level of infestation were evident.

Pea Moths (*Lasperesia* spp.)

Pea pods containing larvae of this insect were discovered during the first week of April. Pod damage varied between plots and was as high as 98% in one plot with 73% of the seeds infested, and only 48% in another where seed infestation was as low as 19%.

Thrips

These insects have been observed mostly in broad bean flowers, and counts as high as 10 thrips per blossom were recorded. *Hypera* and *Linux* species were also observed but have shown no economic damage to date.

The Biology and Control of *Orobanche*: A Review

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Orobanche species, commonly known as broomrapes, are important root parasites of many groups of broad-leaved plants, especially of the Leguminoseae and Solanaceae. They are very widespread throughout the semi-arid regions of the world and are common in Eastern Europe, the Mediterranean basin, the Middle East, Asia, and parts of Russia. In the USA, *Orobanche* spp. have been observed in California, Kentucky, and Louisiana. More than 140 species are reported to parasitize different crops and wild plants. In the Mediterranean region, two major species, namely *O. ramosa* and *O. crenata*, prevail and cause considerable yield losses in tomato, potato, tobacco, sunflower, and broad bean, amongst other crops.

Characteristics of the Genus *Orobanche*

Occurrence and Host Range

All members of the family Orobanchaceae lack chlorophyll and are obligate parasites. Their distribution is wide, encompassing many different environments; however, they thrive best under typical Mediterranean conditions of wet winter and spring, followed by dry summer and fall. It appears that broomrapes are not found in tropical rain forests, which may be because they require a dry and windy atmosphere for seed dissemination.

The host range varies with species of *Orobanche*: 28 crop and ornamental species grown in California and more than 20 weed species have been reported as hosts for *O. ramosa* (branched broomrape). It appears that in the absence of a suitable crop host or after its harvest, the parasite survives and increases through infestation of weed hosts. *Orobanche*, however, has not been reported as infesting monocotyledons, ferns, or gymnosperms.

In the case of legume crops, *O. aegyptiaca*, *O. crenata*, *O. lutea*, and *O. minor* are considered to be serious. Although *O. ramosa* is not listed here, it has been shown to parasitize broad bean plants when grown in greenhouse pots and in Egypt complete yield loss has been found to occur in heavily infested broad beans.

Some plants that are not themselves parasitized by *Orobanche* are known to be able to stimulate the germination of its seeds. These so called trap crops include *Capsicum annum*, *Tridax procumbens*, and *Bidens pilosa*.

Life Cycle and Growth Habit

Orobanche is an annual and its life cycle consists of two phases: firstly the induction of seed germination and the formation of an unconnected seedling; and secondly the attachment of this seedling to the host and the commencement of true parasitism. The latter part of this cycle can further be divided into two stages: the hypogeal stage, lasting for 45–50 days, during which the vegetative subterranean organs develop and food material is removed from the host and accumulated in the parasite; and the epigeal stage, in which the vegetative organs grow rapidly and produce reproductive organs above the ground. This lasts for about 30 days.

Seed Size and Dormancy

In general, *Orobanche* seeds are very minute and produced in abundance. They measure approximately 0.3 × 0.2 mm and it has been reported that one plant of branched broomrape can produce 5000 or more seeds. *O. picridis*, moreover, is known to be able to produce 94 000–116 000 seeds with a 1000 seed weight of 0.0029 g.

The seeds of *O. ramosa* are oval in shape with a narrow micropylar and a wide chalazal end. The seed coat consists of sclerified cells and has a reticulate pattern and encloses a mass of endosperm cells in which is embedded an undifferentiated embryo.

Orobanche seeds undergo a period of dormancy and may need from 18 months to 2 years of storage for the after-ripening processes to take place. After this the seeds can remain viable in the soil for at least 12 years.

Germination

In 1823 it was first shown that broomrape seeds germinate only in the immediate vicinity of a host root. Subsequently a dry residue that could stimulate seed germination when redissolved in water was obtained from the roots of a host. It was shown that no spontaneous germination could occur in *O. crenata* in the absence of such a stimulatory substance. It appears that the chemical stimulant secreted by the host roots can cause germination of seeds up to a distance of 1 cm from the root, but that only seeds within 2 or 3 mm of the root can actually infest the host.

In studies of the effect of root exudates from several crops it was found that seedlings of linseed, maize, and sorghum, which are not parasitized by *O. minor*, had a better stimulating effect on its germination than those of clover, which is a normal host. Linseed had the best stimulatory effect and paper strip chromatography of its root diffusate has shown the stimulatory fluid to consist of more than one substance. This fluid has a reducing power and, on the basis of its relative stability in weakly acidic solutions and instability in alkaline solutions, it has been suggested that the stimulant contains an acidic or potentially acidic lactone group, possibly similar to "strigol," the germination stimulant for *Striga hermonthica* extracted from the roots of cotton. However, tests on a variety of synthetic compounds have shown that organic acids, sugars, amino acids, vitamins, and lactones have no stimulatory activity.

Orobanche seeds need to undergo some metabolic changes before germination and it has been found that gibberellic acid can act as a stimulus to these changes. This may be because the dormant seed contains a low content of endogenous gibberellins and, as a result, responds well to an exogenous source.

Temperatures of between 20 and 25 °C generally favour the germination of the parasite; at a temperature of 25 °C, *O. crenata* has been shown to cause considerably greater damage to broad beans than at 15 °C. There are contradictory reports about the effect of light on *Orobanche* germination; studies on some species have indicated that light may promote germination whereas with others the opposite seems to be the case.

Soil conditions also appear to have some influence on the germination and subsequent growth of the broomrapes. Alkalinity tends to inactivate the germination stimulant rather rapidly; the degree of infestation and timing of the first appearance of the parasite seem to vary with soil type; and the parasite is more troublesome in soils low in fertility. Fertilization, especially with K and P_2O_5, may decrease infestation by promoting early maturity.

Early Development and Anatomy

The early development of the parasite seedling and the establishment of physiological contact with the host is a relatively complex process, considerably influenced by the host itself through its root exudates. Stimulation of the seed by these chemicals causes cells of the radicular pole to expand, possibly without mitotic division, burst through the testa, and grow toward the host root. The radicle penetrates the host root, without causing it much injury, passes through the epidermis and cortex, and, on reaching the stele, forms a channel for the transfer of food materials. The main part of this food channel, or haustorium, is composed of undifferentiated parenchyma. There is no phloem tissue, and the xylem, in contrast to other parasites, consists only of tracheids and may be present as irregular strands. Studies of *O. ramosa* have established the xylem elements and the undifferentiated parenchyma of the host and parasite to be continuous in the haustorium, but no phloem continuity with the host has been observed.

While this haustorial development is proceeding, the external parts of the parasite, slender worm-like rootlets consisting of an epidermis, cortex, and xylem vessels and without root caps or hairs, are being formed. Secondary haustoria develop upon contact between these roots and the roots of the host. The function of these secondary attachments is more likely to be storage rather than physical support or stability.

Cross sections of young *Orobanche* shoots have revealed xylem and phloem elements and a large number of starch grains. No starch grains were evident, however, in mature shoots. The *Orobanche* bract consists of an epidermal layer with trichomes, a spongy mesophyll, and vascular strands, but no palisade cells. The bract cells have been found through electron microscopy to be composed of large vacuoles containing a tannin-like substance, an endoplasmic reticulum mitochondria, and a nucleus. No chloroplasts have been identified in these cells.

Morphology and Seed Production

Orobanche spp. have erect, branched or unbranched, aerial flowering shoots completely devoid of chlorophyll. The leaves, which have stomata, are reduced to scales and are alternate in arrangement. The shoots may be smooth or hairy and they bear the zygomorphic and bisexual tubular flowers in spikes. These flowers have a 4–5-lobed calyx and corolla, are two-lipped, and range in colour from white to faint yellow and from violet to blue. These characteristics imply that insects play an important role in pollination and this is indeed the case, with wind playing little or no role in the process. The four stamens, which are of two different lengths, are attached to the upper lip of the petals as are the two chambered anthers, which usually have spurs designed to cover pollinating insects with pollen. The floral morphology implies adaptation to a specific type of honey or bumblebee and indeed the outer epidermis of the calyx and corolla is covered with stalked glands that may serve to prevent ants and other insects entering the flower, thereby reserving the nectar for the effective pollinators. Cross-pollination is presumably a usual feature of the Orobanchaceae, but parthogenesis has been reported to occur in *O. uniflora*.

The seeds are produced in capsules that dehisce into two halves from the top. Dissemination can be mechanical, through handling, by surface water, carrying seeds below the soil into the rhizosphere of the hosts; or by means of the wind, which is facilitated by cavities in the seed testa and by the fact that after the death of the plant the pedicels remain stiff so that the fruits vibrate in the air like pepperpots.

Chemistry and Physiology

It had been reported that traces of chlorophyll were observable in some species of *Orobanche*, but more recent studies on the pigment system of *O. hederae* have revealed only negligible amounts, if any, of this pigment in chromatographic separations. $^{14}CO_2$ fixation was also shown to be very low in *Orobanche* under either light or dark conditions. However, large amounts of carotenoids, identified as flavochrome, neoxanthin, and flavoxanthin, have been found in *Orobanche* extracts, together with low concentrations of B carotenes. Further studies of acetone extracts of *O. ramosa* shoots with a scanning spectrophotometer have produced absorption spectra different from chlorophyll *a* or *b*, which reinforces the suggestion that pigments other than chlorophyll are found in this parasite.

By using radiolabeled materials, it has been found that materials can move easily from host to parasite in the light, but that translocation of materials from host to parasite in the dark or from parasite to host in general is negligible (Fig. 1). This is considered as further evidence of the heterotrophic nature of the *Orobanche* species. Translocation across the haustorium appears to be apoplastic, whereas that within the shoot is symplastic. A very rapid rate of transport of sugars, herbicides, and water between the root of broad bean and

Fig. 1. Tomato exposed to $^{14}CO_2$ *shows that radiolabled materials could move easily from the host to the parasite (a), whereas no translocation occurred from the parasite to the host when Orobanche was exposed to* $^{14}CO_2$ *(b).*

O. crenata has been noted; and the rate of translocation of 2,4-D applied to the foliage of bean plants to the *Orobanche* parasitizing it was found to be similar to that of sugar translocation. The herbicide accumulated in the *Orobanche* tissue up to a maximum concentration of 14 times that in the bean root at 125 hours after application and thereafter the concentration declined.

Reports concerning the transfer of plant hormones in the host–parasite relationship are conflicting. Flowering was obtained in *O. minor* parasitizing red clover when the host was exposed to a long-day treatment, but not under short-day conditions, indicating the likelihood of a transfer of a specific host-flowering hormone or its precursor to the parasite. However, it was also found possible to induce several species of *Orobanche* to flower on hosts still in their vegetative stage. A partial answer to this anomaly has been provided by further studies that have shown that *Orobanche* is incapable of synthesizing all the necessary growth substances by itself and so must obtain some but not all of these hormones from its host.

Effects of *Orobanche* on the Host

Growth and Yield

Infestations of *Orobanche* may cause severe yield losses to their different host crops. In general, yield reduction is related to the number of parasites per host plant and the earliness of attack. Losses in sunflower due to infestations of *O. cernua* and *O. ramosa* have been reported as ranging from 15 to 34%. *O. crenata* infestations in broad beans have resulted in total crop loss under some conditions.

Water and Minerals

Transpiration in *Orobanche* is extremely high, especially from the scale leaves, where the effective rate may be 35% greater than from the stems or flowers. The active excretion of water from the glandular hairs (hydathodes) rather than from the small and nonfunctional stomata has been shown to be responsible for this major withdrawal of water from the host and the consequent injury inflicted upon it. This injury, it has been emphasized, results more from the decreased ability of the carbohydrate-starved host roots to absorb water from the soil than from the extraction of water by the parasite per se. Moreover, studies have shown that the osmotic pressure of *O. crenata*, while being greater than that of its bean host roots, is less than that of the shoots, implying that water is not removed from the shoots but is diverted directly from the roots of the host.

Broomrape parasitism causes considerable changes in the host's mineral content. Percentages of nitrogen and potassium were reduced in beans infested by *O. crenata*, but no changes in the phosphorus and calcium contents were observed. A comparison of the shoots of the host and the parasite, however, in this case, revealed the parasite to contain higher contents of phosphorus and potassium and lower contents of nitrogen and calcium than its host.

Metabolites

Orobanche infestation has been found to significantly reduce the starch content per gram dry weight of the host, which results from the parasite's dependence on the host's intermediates for its starch synthesis; and to increase the level of phosphorulase activity in the host, which provides an increased supply of readily diffusable carbohydrates for the parasite. Infestation of *Petunia hybida* and *Nicotiana tabacum* by *O. aegytiaca* also resulted in a 35–70% reduction in the hosts' C:N ratio. No marked changes have been found in the net assimilation rate of tomato as a result of broomrape infestation, and it has thus been proposed that the internal factors controlling this, namely photosynthesis and protein synthesis, are not affected by the parasitism.

Control Methods

It appears that, as yet, there is no consistent and economical method for controlling *Orobanche*. However, there are some practices that might prove helpful in reducing or even eradicating this harmful pest.

Mechanical

Control is achieved through the regular cutting of the emerged spikes of the plants. Reductions in infestation of 85% after 2 years and 96% after 4 years have been achieved as a result of weekly hand pulling. Removal of the plants should be carried out before full flower development and collected material should be burnt to ensure that seeds are not dispersed during pulling or left to develop on the detached shoots.

Biological

Fusarium orobanches has been found to be effective in destroying *O. ramosa* in tobacco before the emergence of the shoots and field trials have shown that *Orobanche* in watermelons can be controlled by the application of the fungus extract "product F" with the seed, followed by irrigation. The toxicity of this extract lasted 80 days and was found to be effective against both seeds and seedlings of the parasite.

The mining fly *Phytomyza orobanchia* is reported to cause considerable damage to both *O. cumana* and *O. ramosa*. Approximately 500–1000 insects per hectare are sufficient to kill more than 50% of the broomrapes and prevent the remainder from setting seed.

Livestock have been found to contribute to control by feeding on *O. cernua* and *O. minor* shoots. However, viable seeds are excreted with the feces and thus improper management may result in dissemination rather than control by this means.

Cultural

Although pot experiments have shown that drying helped to kill seeds of *O. ramosa*, unsatisfactory control of the parasite was obtained in dried soil during a summer fallow. However, parasitism of *O. aegyptiaca* is known to be reduced under conditions of insufficient soil moisture. Deep plowing of the soil to a depth of 40–50 cm has also been found to be helpful in reducing *Orobanche* infestation.

Increasing the soil fertility seems to be an effective way of controlling some species (e.g., *O. minor*) and applications of nitrogen, phosphorus, and potassium have been found to reduce infestation by 33–50%, giving a corresponding yield increase in various crops, whereas 250–500 kg/ha dressings of superphosphate have been reported to give partial control of this parasite in clover.

However, other reports indicate that the use of dry fallows, various rotations, heavy manuring, lowering of soil pH, planting in deep furrows, and deep ploughing have all been found largely ineffective as control mechanisms.

Trap crops may also be used in rotations to minimize infestations. Good control has been achieved through ploughing under a crop of *Sinapis alba* at its flowering stage, and by incorporation of dried sunflower meal into the soil prior to planting or transplanting the host crop. However, trap crops may not be an efficient method of control because relatively few of the *Orobanche* seeds present in the infested field are sufficiently close to the trap crop roots to be stimulated into germination.

Crop immunity is considered to be the best method for the control of broomrape. In the case of sunflower, Eastern Europe and the USSR have been using resistant cultivars for the last 30–40 years. The development of resistance in legumes is less advanced, but in certain studies of resistance to *O. crenata* in broad beans, resistant genes tended to be dominant to susceptible ones, and susceptibility to infestation was positively correlated to bean seed weight (e.g., varieties with larger seeds were found to be more susceptible).

For maximum control of *Orobanche* it has been recommended that an integrated program of control involving both cultural and biological mechanisms be used.

Chemical

In vitro Studies — Tests of 237 herbicides over a range of concentrations showed that most of these chemicals were ineffective in inhibiting the germination of seeds of *O. aegyptiaca*. There were, however, several notable exceptions: the phenoxy compounds, which are unfortunately not selective for the common host crops; the phenols and endothal, which show very little persistence; chemicals such as barban, benzadox, diquat, and paraquat, which because they do not show preemergence activity are also unlikely to be useful aids to control; and chloramben, chlorthiamid, dischlobenil, nitralin, and oryzalin, which may prove useful. Further tests have shown that diphenamid, trifluralin, and R 38418 were able to significantly reduce the germination percentage of seeds of *O. ramosa*.

Greenhouse Studies — Of 13 soil-applied herbicides tested, only one (DCU) was found to give consistent control of *Orobanche* on tomato. Two others (Endothal and NAA), although toxic to the parasite, also proved toxic to the tomato host. Tests on herbicides from the dinitroaniline and carbamate groups indicated that: trifluralin reduced *O. ramosa* infestation when incorporated in the soil at transplanting, but when applied after haustoria development was much less effective; CGA 14397 was also effective in controlling *Orobanche*; but Profluralin (CGA 10832), although it increased the dry weight of the tomato host, did not reduce the dry weight of the parasite. With specific regard to legumes, Terbutol applied as a dust with bean seeds at planting has been shown to give maximum bean seed yield with minimum incidence of *O. crenata*.

Glyphosate, applied as a foliar spray, has also been reported to be highly effective in controlling both *O. aegyptiaca* and *O. ramosa*. Rates of application, however, must be low and carefully controlled as the chemical is toxic to the host crops in higher concentrations.

Field Studies — Among the effective soil-applied herbicides, methyl bromide or a 2:1 mixture of methyl bromide with chloropicrin are reported to give the best control of *Orobanche*. However, these chemicals have to be injected into the soil as fumigants and require a 24-hour coverage of the treated area with polythene sheets. For this reason, application on a field scale is likely to be cost-prohibitive. Preplanting applications of Chlorpropham, Dalapon, TCA, and DCU (dichloral urea) and preemergence application of sesone (2,4-DES) and allyl alcohol have variously been reported as effective control measures. Diphenamid and a mixture of diphenamid with trifluralin have been shown to reduce broomrape infestation in tobacco by 62% and 58%, respectively; double applications of methamsodium in November and March have proved effective in killing all seeds of *O. ramosa* and *O. muteli* to a depth of about 25 cm in the soil; and good control of *Orobanche* in broad beans has been obtained through 1,2-dibromo-3-chloropropane applied in irrigation water.

Foliar applications of several compounds appear to give effective broomrape control. Allyl alcohol, applied as a 1% solution at flowering or as a 0.22% solution at 2-week intervals, gave good control of *O. ramosa* in tomatoes. Very effective control of *O. ramosa* and *O. aegyptiaca* in tobacco was achieved using a 2% solution of MH-triethylamine, which was translocated via the host roots into the parasite. Hedolit (based on DNOC) and glyphosate also gave excellent control of *O. ramosa*, and glyphosate has further proved to give good control of *O. crenata* in broad beans when applied after flowering.

A new approach to *Orobanche* control, involving the use of synthetic germination stimulants, is currently under investigation at the Faculty of Agricultural Sciences and preliminary results indicate that host crops planted a few weeks after treatment with GR 7 may escape parasitism.

Work is proceeding at several locations in the Middle East and on several fronts in an attempt to achieve a better understanding of this parasite that causes such dramatic yield reductions in almost all the food legume crops. This understanding, it is hoped, will lead to the evolution of more consistently effective control measures and, in reducing the incidence and severity of infestations in these crops, will contribute considerably to the increased stability and productivity so badly needed in the food legumes.

Broomrape (*Orobanche crenata*) Resistance in Broad Beans: Breeding Work in Egypt

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The parasitic weed broomrape (*Orobanche* sp.) is a severe pest of all legume crops in Egypt. Infestations, particularly of broad beans (*Vicia faba*), which are the most widely cultivated grain legume in the country, cause very high annual crop losses. At present there is no truly effective method for controlling this damaging parasite, and current emphasis is being placed on the development of resistant varieties as the most effective and economic control measure. Four branched and four unbranched species of *Orobanche* have been identified in Egypt. Although all the species infest legume plants, *Orobanche crenata* is without doubt the most serious pest, attacking the important broad bean crop and causing considerable damage.

Comparatively resistant cultivars have been reported in broad beans in Italy, melons in the USSR, and hemp in France and grafting experiments have shown the decisive characters determining resistance to be in the root. In sorghum, which is infested by parasitic plants of *Striga* spp., two forms of resistant mechanism have been found: firstly, resistance arising from the low production of *Striga* germination stimulant by the root, resulting in low infestations due to reduced germination of the parasite; and secondly, resistance based on barriers to the successful establishment of the parasite on the host, either through mechanical obstruction, involving thick-walled endodermis or heavy deposits of silica in the endodermis, or by physiological barriers preventing adequate haustorial nourishment. In addition, research on *Striga* resistance in sorghum has revealed that different strains of the parasite exist and that these differ in their virulence on different hosts. This presents further complications in attempting to achieve a good and stable resistance. A similar situation should be expected in *Orobanche* species.

Screening and Selection for *Orobanche* Resistance in Broad Bean

This program was initiated in 1972 at Giza Research Station. A collection of germ plasm, comprising land strains (families) and hybrid derivative lines, were subjected to selection for three seasons in a heavily infested plot; 315 lines of *Orobanche*-free and less-infected plants selected from this material were then tested against a new unselected population of 121 entries. This investigation showed the percentage of tolerant lines in the selected population to be 44.5, in comparison with 21.0 in the unselected material, thereby illustrating the effectiveness of selection in raising the resistance level in populations.

Evaluation of Promising Tolerant Families

Twenty-two families derived through a 3-year cycle of individual plant selection in an F_7 line of the cross Rebaia 40 (commercial variety) × F 216 (land strain) were evaluated with seven commercial varieties and land strains for *Orobanche* tolerance. Results (Table 1) indicated the family F 402 to have a higher level of tolerance than either the other selected families or the check varieties. Further tests on this family have shown that on average it had 57.5% less *Orobanche* spikes per hill and nearly four times more *Orobanche* free hills (each hill with two bean plants) than the commercial variety Giza 2.

F 402 has also proved to have a high level of field resistance to root rot and wilt

TABLE 1. A comparison of the tolerance of selected families and unselected populations of broad bean to *Orobanche crenata*, Giza Research Station, 1974–75.

Broad bean material	Infestation: No. *Orobanche* spikes/infected plant	% *Orobanche*-free plants	Visual rating[a]
Selected families			
F 402	1.1	22.2	1.3
F 408a	3.3	0.0	2.7
F 403a	4.0	9.1	2.3
F 401	4.3	2.6	3.7
F 410c	4.9	7.5	1.7
Unselected populations			
L 53/536/63	5.9	2.2	5.0
F 216	6.6	0.0	5.0
Giza 2	7.4	0.0	3.3

[a] Visual rating using 1–5 scale: 1, vegetative growth and pod setting almost normal, due to very low infestation; 5, plants stunted and dried out before maturity with few pods set, due to heavy infestation.

diseases caused by species of the genera *Rhizoctonia* and *Fusarium*, in contrast to the commercial varieties Giza 2 and Giza 4, which are severely affected under field conditions. The tolerance of F 402 to both *Orobanche* and root rot/wilt diseases has resulted in seed and straw yields 16.9 and 4.4 times higher respectively than those obtained from Giza 2.

An evaluation of families selected for *Orobanche* tolerance at Giza and Sids, in Middle Egypt, and Shandaweel, in Upper Egypt, conducted at the Shandaweel Station has shown selections originating from Giza to be considerably more tolerant than selections originating from either of the other two sites. This probably reflects the light selection pressure brought to bear on the material from Sids and Shandaweel (one season only), compared to the more intensive selection, over three to five seasons, carried out at Giza. The investigation also revealed that *Orobanche* infestation on F 402 selections was about four times higher than at Giza, where the selections originated. This result suggests that the virulence of the parasite varies with location, or that different physiological races exist.

Evaluation under Controlled Conditions

Screening for tolerance to *Orobanche* under field conditions introduces a number of errors due to the fluctuating parasite population, its distribution around the plants, and other soil and management factors. To enable better estimates to be made of host resistance and to facilitate studies of the nature and mode of inheritance of resistance, the reaction of catch and trap crops, and the variations in virulence of parasite collections from different locations, a technique for creating artificial infestations has been evolved at Giza. This involves inoculating the root mass of a 25-day-old plant in a soil core of 5 cm in diameter with sufficient *Orobanche* seed and then growing the plant under irrigation in a 25-cm pot.

Using this technique, an estimation of *Orobanche* infestation of F 402 and Giza 2 has revealed highly significant reductions in *Orobanche* populations both above and below the surface in the case of F 402 (Table 2). Based on these findings the resistance of F 402 may be ascribed both to reduced production of a germination stimulant and the erection of mechanical and physiological barriers to the successful establishment of the parasite. This resistance is associated with slower tap root growth, less production of lateral roots, and an altogether more compact root mass in F 402 than in other more susceptible varieties, such as Giza 2.

Toward More Resistant Broad Bean Lines

The research efforts to date have primarily involved screening and selection from within the available indigenous germ plasm and from a number of hybrid lines, not

TABLE 2. *Orobanche crenata* infestations of F 402 and Giza 2 under artificial infestation conditions, Giza Research Station, 1977–78 season.

Cultivar	Infestation: No. *Orobanche* stems and spikes/plant: Above soil surface	Below soil surface	Total	% of total above soil surface	Max. spike height	% *Orobanche*-free plants (above surface)
F402	2.2	13.4	15.6	14.1	1.8	53.9
Giza 2	11.4	26.1	37.5	30.8	10.6	0.0

specially bred for *Orobanche* resistance. Although this selection program has proved to be fairly successful in increasing the level of resistance in populations, the rather narrow genetic base and geographical spread of the screening nurseries inherent in the work means that a ceiling will soon be reached in improvement achievements.

For the future, a truly effective breeding program must combine a massive amount of screening of a wide range of material over a large number of locations with studies of a wide collection of parasite seed under artificial infestation conditions. This will enable the identification of sources of resistance to the suspected different races of the parasite as well as the clarification of the different resistance mechanisms. Once defined, this resistance can be introduced into adapted lines by multiple hybridization followed by recurrent selection to obtain lines that are both highly productive under a variety of environmental conditions and resistant to *Orobanche*.

In this way the highly destructive effect of this parasite on the very important broad bean crop in Egypt can, it is hoped, be greatly reduced, if not completely eliminated.

Accentuation of Weed Control Problems in the Dry Areas with Relevance to Herbicides in Food Legumes

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Over a large part of the subtropical, semi-arid zone, both highland and lowland, a cereal–fallow rotation system has traditionally been practiced. The main weed control methods in such a system have involved grazing during the fallow period and cultivation prior to planting the cereal crop. For economic reasons the largest possible area is maintained under cereals each year and as a result grazing has often been reduced to the off-season or in some cases completely abandoned. This has allowed the proliferation of many winter weeds, which infest autumn-sown cereal and legume crops, because by the time that grazing occurs these weeds have already, to a large extent, shed their seeds. With this increasing tendency toward intensification of cropping systems, curative weed control is becoming imperative to the maintenance of high levels of productivity.

Constraints of Curative Weed Control in Dry Areas

Water availability is the major factor affecting the productivity of crops in the dry areas. Even in good years the productivity of field crops in these areas is suboptimal and the profitability is generally low and variable. Farmers thus attempt to minimize the cost of their inputs and avoid as far as is possible the relatively costly fertilizers and pesticides that are applied early in the cropping season and that would thus be wasted in the event of crop failure due to insufficient rainfall.

At present the feasible curative weed control methods available are threefold:

Firstly, there is manual weeding, which can be through hand pulling in broadcast crops and where weeds are well established, or with tools if the crop is row planted or the weeds are not too far developed. Farmers often use hand-pulled weeds as animal fodder but although this may at first sight seem a very useful practice, to be suitable for fodder the weeds must have reached a certain size and will have already exerted a considerable yield-reducing effect on the crop by the time they are removed. Manual weeding is very labour intensive and according to recent studies at ICARDA requires at least 60 man-days per hectare for the minimal two weedings that are necessary. The advantage of this control method, however, is that it can be foregone in the event of crop failure due to drought.

Mechanical weeding is the second available control practice and involves the use of animal or tractor power. It can only be carried out in row-planted crops and where the rows are sufficiently spaced to allow for the passage of the machine without causing severe crop damage. This method is ineffective for the control of in-row weeds; requires a relatively level soil surface; can cause considerable soil compaction and loss of soil moisture; and is not possible when the land is wet. However, considerable savings in labour can be made over manual weeding, although investment in machinery may be high and increases with decreasing between-row spacing, meaning that fewer plants can be grown on a given area unless investment is considerable. These requirements and disadvantages have tended to hamper the widespread introduction of mechanical methods in the relatively poor marginal areas.

Finally there is chemical weed control. This requires some skill and accuracy to apply the right herbicide at the right dosage at the right time and again considerable investment in equipment. Results can be excellent when the chemicals are used in the correct way but lack of operator skill and variable environmental conditions can result in total wastage of the investment or even destruction of the crop being treated. In addition, the use of herbicides can considerably reduce moisture loss as no soil disturbance is generally required and as water-consuming weeds are effectively eliminated. However, despite the cost of chemical control in most of the countries of the dryland region being far below that of correspondingly effective manual methods, the relatively high risks involved in their use and the high costs of the chemicals, which are largely imported, have so far inhibited the large-scale use of herbicides, especially by the small farmers.

A better understanding of the actions of these chemicals under dryland conditions will perhaps enable us to evolve recommendations and procedures that will reduce the risks and costs of this more effective and economic means of weed control and as a result increase its popularity with the farming community.

Selectivity Mechanisms of Soil Herbicides

Phytotoxic chemicals have a very wide range of modes of action. Amongst the soil herbicides these include retarding root growth, inhibiting photosynthesis, interfering in cell meiosis, and affecting the uptake of minerals and water, to name but a few. Irrespective of their modes of action all chemicals must first be absorbed by the plant and translocated to their place of action before they can begin to be effective. In considering herbicides we would do well to remember Paracelsus' assertion of 500 years ago, that all substances are poisonous to living organisms at a certain quantity. The critical factor to be considered is thus the quantity of the herbicide that reaches its specific site of action. The variation in this determines the selectivity of the chemical (i.e., which plants will be killed by a certain dosage of herbicide under certain conditions and which plants under the same conditions will survive). Selectivity is of tantamount importance in the use of herbicides and it may be achieved by a number of different mechanisms. These mechanisms include physical placement of the chemical; ease of penetration of the root epidermis; metabolism to harmless derivatives within the plant; and ease of transport within the plant. In hydroponic culture the explanation would stop here, but in agriculture the soil, which is the link between the application of the chemical and its absorption by the plant, plays a very important role in determining the action of herbicides, most of which are soil applied. The soil represents a very complex system but certain important factors, such as quantity of water in the soil, adsorption of herbicides on soil particles, and movement of herbicides in the soil, that affect selectivity can be identified.

Quantity of Water in the Soil

Herbicides are translocated within the soil from their site of placement to their site of uptake either in solution with water or in a gaseous state. Chemicals commonly absorbed in solution include the groups of substituted ureas, uracils, triazines, diphenylethers, acetamides, and thiocarbamates, which are mainly applied to the soil surface. Gas-transported chemicals are largely of the group of nitroanilines generally incorporated in the soil prior to planting due to their high vapour pressure.

With solution-absorbed herbicides, uptake by the plant depends to a large extent on the water solubility of the chemical, which is in turn affected by the temperature and pH of the soil water and the rate of plant water uptake. In this context, the amount of available soil water is very important, as with less water to dissolve a given quantity of chemical the resulting solution will be more concentrated and the amount of chemical taken up by the plant over a fixed time will thus be greater. Thus it appears that, providing a chemical dissolves readily in water, its action will be considerably more vigorous under dry soil conditions than when the soil is wet. Comparison of the quantity of water required to dissolve a given quantity of various chemicals could thus be used as a good guide to the chemicals likely to act more aggressively under dry land conditions.

Chemical	Solubility in water	Amt water to dissolve 1 kg	mm rain required to dissolve 1 kg	End effect
A	1000 ppm	1 m^3	0.1	Increased
B	100 ppm	10 m^3	1.0	Increased
C	10 ppm	100 m^3	10.0	Increased
D	1 ppm	1000 m^3	100.0	Normal
E	0.1 ppm	10000 m^3	1000.0	Ineffective

The application of high dosages of herbicides with very low solubilities (e.g., E) is a waste of resources under dry conditions because much of the chemical will remain immobilized in the soil due to insufficient water. However, above the level of 1 ppm solubility (A, B, and C), the total quantity of chemical can be dissolved in increasingly less soil water, the concentration of chemical in solution is increased, and, as the degree of interplant selectivity is not altered, the effect on the crop is considerably enhanced (Table 1).

In general those herbicides that are translocated and absorbed by plants in their gaseous state have a very low solubility in water. This fact largely prevents the absorption of these chemicals through the soil-water solution and movement to the plant is thus mainly by means of the soil-air system. The moisture condition of the soil is also a crucial factor in influencing the action of these herbicides, because the rate of diffusion depends largely on the available airspace in the soil. When the soil is in a dry condition a larger proportion of the soil pores are air-filled, as opposed to water filled, and the soil airspace is thus greater. Greater airspace means more rapid diffusion of the chemicals in the soil and enhanced absorption by the plant. Thus herbicides taken up by plants in their gaseous state are also more aggressive under dryland conditions.

Adsorption of Herbicides on Soil Particles

A further factor bearing on the action of herbicides is the degree to which they are adsorbed onto soil particles. The amount of adsorption depends on a number of factors related to the nature of the soil and of the specific chemical. This phenomenon significantly reduces and balances the quantity of herbicides available to the plants and thus considerably affects their activity.

It has been shown that within a group of herbicides (which therefore have a similar means of bonding) the amount of adsorption is positively correlated to the chemical's solubility in water (Table 2). This therefore balances to some degree the increased aggressiveness shown by highly soluble chemicals under dryland conditions.

The physical and chemical properties of the soil play a very important role in determining the degree of herbicide adsorption. Soil particle size is particularly significant in this respect, in that small particles offer a larger surface area for adsorption per unit area of soil. Thus the degree of adsorption increases with decreasing soil particle size. This effect, however, is modified by the relative reactivity of the particle surface, expressed in the cation exchange capacity. Because the soils of the arid zones are usually low in soil constituents with a high cation exchange capacity, such as organic matter, vermiculite, montmorillonite, and illite (Table 2), the amount of herbicide adsorbed is relatively low

TABLE 1. Solubility and selective rates of some herbicides (from various sources).

Herbicide	Solubility in water *(ppm)*	Selective rates recommended *(kg active ingredient/ha)*
Fluorodifen	2	2.0–4.0
Simazine	5	0.25–1.0
Prometryne	48	1.0–2.0
Methabenzthiazuron	59	2.0–4.0
Linuron	75	0.5–1.0
Alachlor	240	1.0–2.0
Metolachlor	530	1.0–2.0
Metribuzin	1200	0.5–1.0

TABLE 2. Magnitude of adsorption on Na-montmorillonite of selected herbicides with different solubilities in water expressed with Freundlich "k" and "n" values.[a]

Adsorbate	Water solubility (*ppm*)	"k" value	"n" value
Simetone	3200	2200	3.23
Atratone	1800	400	2.08
Prometone	750	150	1.56
Trietazine	20	58	1.00
Propazine	8	18	0.89
Atrazine	70	15	1.18

[a] Source: Bailey, G. W. et al. 1968. Adsorption of organic herbicides by montmorillonite soil. Sci. Soc. Amer. Proc. 32: 222.

and its availability to plants correspondingly high. This means that the effect of the herbicide will be greater than in more highly adsorptive soils.

High soil pH reduces the degree of adsorption especially with herbicides that depend on an acid-charged particle surface or on the weak positivity of their radicals (nitrogen in the case of anilines, ureas, and carbamates) for adsorption. Most soils found in the arid lands have a pH of greater than or equal to 8 and thus tend to adsorb chemicals much less readily than the majority of soils.

Environmental conditions such as temperature also have a considerable effect on the adsorption properties of soils. As high temperatures tend to decrease adsorption, particular attention must be paid to treating summer- or autumn-sown crops in the dry areas.

Movement of Herbicides in the Soil

The direction and amount of a herbicide transported in the soil, or the ability of it to diffuse from one place to another, depends largely on the amount and frequency of water infiltration into the soil and the degree of adsorption by the soil particles. When precipitation and infiltration are high, the chemical tends to be leached downward and diluted within a large quantity of soil. This increases the degree of adsorption and further reduces the effect of the herbicide by reducing its concentration in the root zone where it must remain to be effective. In contrast to this, under dryland conditions the dilution of the chemical is less, as a result of less water infiltrating into the soil and so the effect of the herbicide is enhanced. This is further exacerbated by reconcentration of the herbicide near the soil surface as a result of upward soil water movement during spells of dry weather.

It can be seen that the factors underlying the behaviour and efficacy of soil herbicides are of a very complex nature. Much work needs to be carried out to evolve recommendations for herbicide use suited to the specific situation of the arid zones. However, with the knowledge that soil herbicides act more aggressively under dryland conditions, weed control methods can now be developed involving smaller quantities of chemicals. This will reduce the cost of treatments to a level that will better suit the low-cost input requirements of the agricultural systems of the Middle East and North Africa.

Section V
Food Legume Development

Genetic Resources of Grain Legumes in the Middle East

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Genetic resources form the base for all crop improvement efforts. Our obligation to avoid loss of genetic variability through the preservation and maintenance of these resources is thus of vital importance to future plant-breeding efforts. This task may be accomplished through a number of means, including cold storage of seeds, and the establishment of gene parks and gene banks. However, the first necessity of any conservation is to ensure that the resource base is made as wide as possible by extensive and thorough collection of varieties from their habitats before they are completely replaced by improved cultivars or otherwise lost.

The Middle East is very rich in the genetic resources of many crops, especially pulses, and several species are considered to have originated there. Although Vavilov's "Centres of Origin" are no longer considered to be centres in the sense in which he described them, the areas concerned, and especially the Fertile Crescent, are important areas of diversity where many related wild species have been found to occur. There have been many collection efforts in the region, but most have tended to place special emphasis on the cereal species. Pulse collections are quite reasonable in quality, but specific gaps remain that it may not now be possible to fill with original germ plasm because of replacement of land races by improved cultivars. The International Board for Plant Genetic Resources (IBPGR), established in 1974 to stimulate germ-plasm conservation, lists southwest Asia and the Mediterranean as top priority areas for the conservation of primitive cultivars and their wild relatives. Full-scale collection of pulses in the region probably needs to continue for a further 10 years to ensure an adequate coverage of all the countries through searches based on a reasonably sized grid system.

Occurrence and Diversity of Grain Legumes in the Middle East

Most of the important subtropical grain legumes can trace their origins to the Middle East area. However, two notable exceptions are *Phaseolus* and *Vigna*, which, although originating outside the region, have achieved considerable importance within it. Although collections of these crops in the region would not yield primitive cultivars or wild relatives as with the other legumes, they would provide good examples of the local variation and adaptation achieved over the centuries by these crops.

Phaseolus

Phaseolus beans (*P. vulgaris* L.) probably originated in Mexico and South America and were only introduced into the Middle East after the Spanish conquests. Since then they have become widespread in the region. Lima beans (*P. lunatus* L.) were also introduced about this time but have spread comparatively little.

Pisum

Peas are found in three main centres: the Mediterranean, Ethiopia, and Central Asia, the Near East being considered a secondary centre. Only two species are now recognized: *P. sativum* L., which includes *P. elatius* (M.Bieb) Aschers & Graebn. and *P. humile* (Mil), as varieties due to proven intercrossing; and *P. fulvum* (Sibth. & Smith). Some authorities (Townsend) still consider *P. formosum* (Stev) Alef., a perennial species, as belonging to *Pisum* and not to the separate genus *Vavilovia* despite the absence of intercrossing with peas.

Cicer

Chick-peas probably have their origins in the Middle East–Mediterranean complex. The closest relative crossable with chick-pea, *Cicer reticulatum* Ladizinsky, is found in southeastern Turkey, and other morphologically closely related species such as *C. bijugum* (K. H. Rech) and *C. echinospermum* (P. H. Davis) also occur in this area. Substantial evidence for the relations between these species has been provided by Ladizinsky and Adler (1976).

Chick-peas were introduced into India and Ethiopia in ancient times, and secondary centres of variability now exist in these areas. The kabuli-type chick-pea (large-seeded, cream-coloured, and white-flowered) preferred in the Middle East was introduced into India in the 18h century and into Ethiopia only this century.

Lens

Lentils probably also originated in the Middle East. *Lens orientalis* (Boiss) Hand. Mazz. certainly had a part in the ancestry of the cultivated lentil and according to some authorities (Williams et al. 1974) should be considered to be subspecies of the lentil (*L. culinaris* Medik). The genus *Lens* is difficult to separate from *Vicia* and *Lathyrus* and at present is considered to consist of five species (Table 1).

Vicia

This genus contains about 150 species in the temperate parts of the northern hemisphere and South America. Of these, 59 have been found to occur in Turkey and 22 in Iraq. Broad bean (*V. faba* L.) and bitter vetch (*V. ervilia* L. Willd.) are important as grain legumes, and many other species, especially *V. sativa* L., are used as animal fodder in natural or cultivated pasture.

Broad beans seem to have originated in the Near East (northern Iran) and to have spread to Europe, North Africa, and Spain along the Nile to Ethiopia and through Mesopotamia to India. The crop is also widely grown in China where it has been known since A.D. 1200. Other species in the division *Faba* of the genus are *V. bithynica* L., *V. narbonensis* L., *V. galilaea* (Plitm. & Zoh), and *V. hyaeniscyamus* (Mout). Although these are morphologically related, studies of cytology, crossability, and seed protein profiles have ruled them out as wild progenitors of broad bean. Nevertheless a common ancestry can still be postulated for these species.

Common vetch is grown throughout Europe and Asia, except in the extreme north and in the tropical areas. In other continents it is a naturalized introduction. The variety *angustifolia* L. is perhaps the original wild ancestor but, in general, the seeds have proved difficult to trace in archaeological work and so relatively little is known of the origins of this species.

Vigna

Cowpea, *V. unguiculata* (L.) Walp., originated in Ethiopia and the subspecies *dekindtiana* (Harma) Vardc. is now quite common in the wild throughout Africa. It arrived in the Middle East via India sometime before 300 B.C. and is now grown under irrigation

TABLE 1. Distribution, altitude, and flowering season of grain legume species and some of their wild relatives.

Genus	Species	Area	Altitude	Flowering
Pisum	*sativum* L. subsp. *sativum* var. *sativum*	Middle East, cosmopolitan	0–2000	Apr–May
	sativum L. subsp. *sativum* var. *arvense* (L.)	Mediterranean, S.W. Asia, Ethiopia, cult. cosmopolitan	0–2400	Apr–May
	sativum L. subsp. *elatius* var. *elatius*	Mediterranean, Crimea, Middle East, Caucasus	700–1600	
	sativum L. subsp. *elatius* var. *pumilio*	Middle East, Cyprus	700–1600	Apr–May
	sativum L. subsp. *abyssinicum*	N. Ethiopia	2000–2400	Sep–Oct
	fulvum	S. Turkey, W. Syria, Lebanon, Jordan, Israel		Jun–Jul
	formosum var. *formosum*	Lebanon, Turkey Caucasus, Iran		
	var. *pubescens*	Iraq, S. E. Turkey	2900–3350	Aug–Sep
Cicer	*reticulatum*	S.E. Turkey	500–1500	Jun
	heterophyllum	Manavgat-Akseki	1100	May (Jun)
Lens	*culinaris*	Mediterranean, S.W. Asia, India, China, America	0–2900	Apr–Jun (M. East)
	ervoides	S. Europe, N.W. Africa, S.W. Turkey, W. Syria N. Israel, Crimea, Caucasus	0–600	Apr–May
	montbretii	S.E. Turkey, N. Iraq	1000–1300	Apr–May
	nigricans	Spain, Morocco, Aegean, Turkey, Crimea, E. Mediterranean	0–900	May
	orientalis	Turkey, Syria, Greece, Israel, N. Iraq, W & N Iran, Transcaucasia	450–1300	Apr–May
Vicia	*faba* L. var. *faba* (= var. *major*)	Mediterranean, Yemen, USSR,	0–3000	Feb–May
		M. East, cosmopolitan		Jan–May
	var. *equina*	Mediterranean	0–1500?	Feb–Apr
		M. East		Jan–Jun
	var. *minuta* (= var. *minor*)	Near East	0–3200	Jan–May
		Ethiopia, N. India, Tibet		Jan–Feb–Jul?
		Afghanistan	0–4000	
	narbonensis L. var. *narbonensis*	Mediterranean, C. & S. Europe	0–1500	Mar–Jun
	var. *serratifolia*	M. East, India, C. Asia	50–350	Mar–Jun

(*con't.*)

(*Table 1 concluded*)

	galilaea	Israel, Syria, Turkey, Lebanon	0–1300	Mar–Jun
	bithynica L.	W. Syria, Cyprus, Crimea, W.& S. Europe, N.W. Africa	0–500?	Mar–Jun
	hyaenischamus	Turkey, Syria, Lebanon, Israel	0–1300	Mar–Jun
	ervilia (L.)	Mediterranean, M. East, Afghanistan	0–3100	Apr–Jun
	sativa L. var. *angustifolia* L.	Europe to China & India, N. Africa, naturalized in Australia, S. Africa, W. Indies	0–1300	Feb–May; Nov
	var. *sativa*	Same as above	0–1700	Mar–Jun
	var. *amphicarpa*	S. Europe, N. Africa, Middle East, Caucasus	100–700	Mar-Apr
Lathyrus	*sativus* L.	M. East, Europe	0–100	Mar–May
		N. Africa	0–	Mar–May
		N. India	0–	Jan–Feb
		C. Asia, Afghanistan	200–3100	Jul–Sep
		Ethiopia	1800–2000	May–Jun

as a summer vegetable, gram, or fodder crop. *Vigna radiata* (L.) Wilzek. (green gram or mungbean) and *V. mungo* (L.) Hepper. (black gram) are natives of India and have spread to parts of the Middle East.

Lathyrus

This is a large genus comprising about 130 species that are found all over the temperate region of the northern hemisphere and the high altitudes of tropical Africa and South America. Many species are useful as fodders or in pasture and about 20 species are of horticultural interest.

Chickling vetch, *L. sativus* L., is the most important species in the Middle East and is sometimes used for human consumption though more commonly as a cattle feed. Its presumed area of origin is in southwestern and central Asia, but its widespread cultivation and naturalization throughout Europe (excepting the north), the Mediterranean, Sudan, Ethiopia, Afghanistan, and northern India have obscured its native distribution. The Middle East is obviously an important area of diversity.

Lupinus

In total, about 300–400 species exist within this genus and lupins have achieved considerable importance in the Middle East. *Lupinus albus* L. (= *L. termis* Forsk., Egyptian lupin) originated in the Balkans and *L. mutabilis* probably in South America.

Materials Requiring Collection and Maintenance

Four distinct types of material can be identified as ingredients for any germ-plasm collection:

Cultivars in Current Use

Currently used cultivars have an important place in germ-plasm collections as they are usually the starting point for the development of improved varieties. The need to maintain pure cultivars is obvious and for some cross-pollinated crops (e.g., broad beans) this is not a simple task.

Primitive Cultivars

This category of material requires urgent maintenance as many landraces of certain crops have already disappeared or are only available as a negligible admixture with other improved varieties. This is especially the case with chick-peas in Turkey.

Wild and Weedy Species

Wild species are often useful sources of disease resistance and tolerance to adverse environmental conditions. For example, *Cicer reticulatum* and *C. judaicum* (Boiss.) have been found to be resistant to *Ascochyta* blight and *Fusarium* wilt of chick-pea, respectively. Despite initial difficulties experienced in crossing wild species to cultivated ones, modern techniques may eventually overcome these problems and allow the exploitation of such useful resources. Until recently, accessions of wild species have only been entered in small numbers and screening has only just got under way.

As these species often occur in small isolated populations, genetic variability may be considerable and it should be stressed that more accessions of each species should be collected as a priority.

Genetic Stocks and Mutants

These materials fulfill a useful purpose in breeding programs as semifinished products and, when certain characteristics are required, they can be drawn upon as a readily available stock of already evaluated material. Such material must also be given proper maintenance at genetic resource centres.

Pulse Germ-Plasm Collection Efforts and Existing Collections

Since 1920, over 40 collection trips throughout the Middle East and the Mediterranean area have contributed a large amount of legume germ plasm to agricultural research institutes. This has been supplemented by material gathered in the course of collection trips in the region primarily aimed at other species (e.g., cereals).

Collections of varying size exist both within and outside the region. Within the region, Algeria (INRA, Jardin d'Essais, Algiers), Israel (Rehovot), Pakistan (Lyallpur and Tandojam), and Turkey (Iskisehir) have had small- to medium-sized collections for a considerable time. Larger collections have recently been established at the Ege Agricultural Research Institute near Izmir in Turkey and at ICARDA at Aleppo in Syria. In addition, national research institutes throughout the region house small but useful collections of legume species. In India, apart from the relatively recent collection at ICRISAT at Hyderabad, there are sizeable collections of pulse species at Hissar, Pantnagar, and New Delhi. Other institutions outside the Middle East, such as the NI Vavilov Institute in Leningrad, the Institute of Agronomy at Bari (Italy), and the Zentral Institut fur Genetik und Kulturpflanzenforschung in the German Democratic Republic, also house considerable collections of pulse germ plasm from the region.

The contents of some of the more important legume collections are summarized in Table 2. Obvious duplication and triplication exist in these and other collections but for reasons of safety this is generally considered to be an advantage.

Conservation

Conservation of genetic resources primarily involves the long-term cold storage of seeds. Most grain legumes can be stored, as orthodox seeds, at–18 °C and 5% seed humidity for long periods, perhaps up to a century. However, very few long-term

TABLE 2. Some important collections containing grain legume germ plasm from the Middle East.

Institute	Crop	No. of samples
Germ plasm Laboratory, Instituto di Agronomia, Bari, Italy	*Cicer arietinum*	100
	Pisum	700
	Vicia faba	60
	Vicia sativa	900
Ege Agricultural Research and Introduction Centre, P.O. Box 9, Menemen Izmir, Turkey	*Cicer arietinum*	217
	Forage legumes	2146
	Lens culinaris	142
	Phaseolus vulgaris	966
	Vicia faba	135
NI Vavilov All-Union Inst. of Plant Industry (VIR), 44 Herzen Street, Leningrad 19000 USSR	*Cicer arietinum*	27
	Lathyrus sativus	62
	Lens culinaris	24
	Phaseolus spp.	76
	Pisum spp.	164
	Vicia ervilia	3
	Vicia faba	26
	Vicia sativa	42
	All pulses	25000
Zentralinstitut fur Genetik und Kulturpflanzen forschung, Gatersleben, Kreis Aschersleben, German Democratic Republic	*Cicer arietinum*	65
	Lathyrus	288
	Lens culinaris	193
	Phaseolus spp.	1856
	Pisum sativum	1232
	Vicia faba	434
	Vicia spp.	788
ICRISAT, 1-11-256 Begumpet, Hyderabad 500 016, A. P. India	*Cajanus cajan*	6000
	Cicer arietinum	11500
	Cicer spp.	47
ICARDA, P.O. Box 5466, Aleppo, Syria	*Cicer arietinum*	
	Lathyrus sativus	
	Lens culinaris	
	Pisum sativum	
	Vicia ervilia	
	Vicia faba	
	Vicia sativa	

cold-storage rooms are operational and in the Middle East only Izmir has these facilities at present. As a consequence, medium-term storage at 4–16 °C is more usually practiced. Naphtalene balls as an insect repellant have been found to be a useful complement to this method, but where soft-coated seeds (i.e., chick-peas) remain in close contact with the chemical for too long growth, grow out will be stunted. Between storage periods, seeds must be grown out for rejuvenation and the population structure should be maintained as well as possible. The size of the sample in store should not be too small: 5000 seeds or .5–2 kg is sufficient for homogeneous samples.

Perennial wild species pose considerably more difficulties in growing out. Other conservation methods, such as natural reserves where farming is prohibited and gene parks with low- or medium-grazing intensities, are thus often advocated for such material. The use and size of these facilities is still at present under discussion.

Evaluation and Information

Elite germ plasm can be more closely evaluated in replications. At present, evaluation of large amounts of germ-plasm samples are hampered by the lack of detailed replicated and multilocation trials. Detailed cataloguing of germ-plasm collections will be required in the near future and computerization will become essential in this process. This is one area, together with collection missions and germ-plasm exchange, where the benefits of much closer cooperation between national, regional, and international institutions are considerable. Such cooperation would do much to hasten the achievement of a comprehensive and catalogued "world" germ-plasm collection to which every research institute could have access.

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Strategies for the Genetic Improvement of Lentils, Broad Beans, and Chick-peas, with Special Emphasis on Research at ICARDA

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With the establishment of ICARDA in 1977, incorporating the food legume improvement program of ALAD, which was originally initiated in 1972 with funding from IDRC, a considerable expansion in the objectives and scope of legume improvement activities became possible.

The overall objective of the food legume breeding program of ICARDA is thus to encourage and support national food legume improvement efforts through:

- the collection, maintenance, development, and distribution of genetic materials of lentils (*Lens culinaris*), broad beans (*Vicia faba*), and chick-peas (*Cicer arietinum*);
- the undertaking of genetic improvement work and applied research in the areas of breeding and genetics, and the widespread dissemination of research results;
- the training of scientists from the national research programs of the region in the techniques and theory of food legume improvement; and
- the building of an international network of food legume researchers to engender increased cooperation and understanding between programs and thereby to facilitate the free exchange of research results and materials.

The International Cooperative Breeding Program

Breeding work is being conducted in Syria and Lebanon to serve the needs of the low and medium elevation Mediterranean-type environments, and near Tabriz in northern Iran for the development of food legumes adapted to the more extreme high elevation conditions. Although these locations represent a considerable range of environments, they are not representative of the entire range of conditions under which broad beans, lentils, and chick-peas are grown throughout the world; from the Andean region of Latin America and the irrigated conditions of Egypt and the Sudan to the "Rabi" production following the monsoon in India and Southeast Asia.

To adequately address the needs of the national programs in all these differing environments, the ALAD Regional Nursery Program has been expanded into an International Cooperative Breeding Program that aims: to provide for the widespread dissemination of promising elite genetic materials; to make available to the national programs materials exhibiting special characteristics (such as disease resistance) for further evaluation, testing, and possibly also hybridization; to disseminate promising early generation segregating material for development under local environments; and to provide a mechanism for the multilocation testing of elite lines to reduce the time necessary for evaluation prior to cultivar release and allow the identification of genotypes with wide adaptability.

The materials distributed by ICARDA under this program include nurseries of selected germ plasm and(or) advanced lines for screening, evaluation, or hybridization; early generation segregating populations (usually F3 bulks); and yield trials.

Lentil Breeding

The lentil improvement program aims to develop materials of both the *macrospermae* and *microspermae* types with acceptable organoleptic and nutritional quality and possessing the following attributes:

A high and stable dry seed yield through:
- an inherently high yield potential
- tolerance to stress conditions (cold, heat, drought, salinity)
- resistance to the major diseases and pests (including *Orobanche*)
- high plasticity;

A wide adaptability, primarily as a result of reduced photoperiod and temperature sensitivity;

A high total biological yield;

Characteristics suited to mechanized harvesting:
- a tall erect growth habit
- resistance to lodging and pod shattering
- pods borne high above the ground.

Disease and Pest Resistance

Lentils are comparatively free from major disease problems. However, the most serious and ubiquitous problem is wilt, a disease that can be caused by a complex of a number of different pathogens including *Fusarium oxysporum* F.sp. *lentis*, *F. orthoceras*, F. *avenaceum*, *Rhizoctonia solani*, and *Sclerotium rolfsii*. Survey work is urgently required to establish the relative importance and distribution of these pathogens, so that breeding efforts can be directed toward developing multiple resistance to the most important species.

The only other disease of major importance in lentils is rust, caused by *Uromyces fabae*, which can be particularly severe in some parts of the Indian sub-continent, but is rarely a major problem in the Middle East. Some sources of rust resistance have already been identified in India, and it is planned to screen for further sources of resistance in the field using artificial inoculation techniques, at a coastal location in Syria, where the disease can be severe.

Breeding for resistance to other lentil diseases, such as downy mildew (*Peronospora lentis*), *Ascochyta* blight (*Ascochyta lentis*), pea enation mosaic virus (PEMV), alfalfa mosaic virus (AMV), bean yellow mosaic virus (BYMV), and pea leaf roll virus (PLRV), will only receive minor attention at present.

Several insect pests have been reported to cause severe losses in lentils both in the field and in store. These include: pod borers (*Etiella zinckinella*), reported to be the major insect field pest of lentils in India; several species of aphids; *Sitona* weevils; and storage pests, such as the lentil beetle (*Bruchus analis*). No good sources of resistance have been reported to any of these pests, although differential reactions to infestation have been observed and there are other encouraging signs that the development of resistant cultivars may be possible. In breeding for resistance to bruchid beetles care must be taken to ensure that resistance is not associated with poor cooking quality.

Initial screening of lentil germ plasm for resistance to the parasitic weed *Orobanche* is under way and cultivar differences in the degree of susceptibility have already been recorded. This work will be continued and expanded in the future.

Wider Adaptability

Lentils are long-day sensitive plants and it is felt that this is an important factor contributing to the very narrow adaptability of most local cultivars. Narrow adaptability severely limits the progress that can be made through breeding, and the development of cultivars with a reduced photoperiod/temperature sensitivity is thus an important objective of the program. In an attempt to achieve this, selections will be made alternately for yielding ability under long-day conditions (in Aleppo or Tabriz), and for earliness and vigour under short days (in Egypt or Ethiopia) in generations following crosses between genotypes adapted to each environment.

Genotypes with wide adaptability can also be identified through the international cooperative trials and nurseries, and in fact several lines identified as being widely adapted in nurseries conducted under the ALAD program have already been included as parents in the hybridization program at ICARDA.

Improved Plant Ideotype

The development of plants with a larger vegetative frame and a high total biological yield is considered to be of great importance in the strategy for lentil improvement. This is primarily because a high total biological yield is indicative of improved efficiency characteristics, such as a high crop growth rate (CGR) and leaf area index (LAI), and will result in a higher total seed yield, providing that the harvest index is not allowed to fall. In addition, larger, more plastic plants might be reasonably expected to be more stable and to have lower optimum seeding rates, thus allowing considerable savings on the very high rates of seed currently used in much of the region. Combined with resistance to lodging such plants would also allow for easier mechanized harvesting, and would furthermore provide an increased volume of straw for animal fodder, which is a very important consideration in many countries. A more vigorous early growth might also increase the crop's competitiveness with weeds.

The identification of genotypes capable of continued growth at the high temperatures that frequently limit the spring growth of present cultivars, might be a useful start on the road to the development of cultivars with a higher total biological yield.

Germ Plasm

The conservation of genetic resources of lentils has received relatively little attention and germ-plasm collections are generally considered incomplete. The ICARDA collection now stands at nearly 4500 accessions and although many countries are well represented (Table 1), more germ plasm is being sought, especially from North Africa, Bangladesh, the

TABLE 1. Origin of lentil and broad bean entries in the ICARDA germ-plasm collections.

	No. accessions			No. accessions	
Country	Lentils	Broad beans	Country	Lentils	Broad beans
Afghanistan	116	89	Japan	–	5
Algeria	8	18	Jordan	38	9
Argentina	3	1	Lebanon	47	14
Bulgaria	2	1	Mexico	24	1
Bolivia	–	1	Morocco	16	13
Canada	1	–	Nepal	10	1
Chile	178	3	Pakistan	24	6
Colombia	10	14	Palestine	1	7
Costa Rica	1	–	Peru	2	1
Ceylon	–	2	Poland	–	12
Cyprus	6	10	Portugal	–	5
Czechoslovakia	1	–	S. Africa	–	1
Ecuador	6	13	Somalia	1	–
Egypt	62	59	Spain	10	62
Ethiopia	359	105	Sudan	1	32
Finland	–	23	Sweden	–	9
France	2	11	Switzerland	–	1
Germany	–	41	Syria	92	38
Greece	53	5	Tunisia	7	38
Guatemala	3	–	Turkey	290	119
Holland	–	98	UK	–	69
Hungary	49	12	USA	–	3
India	1759	7	USSR	65	21
Iran	1006	13	Yemen	3	5
Iraq	20	49	Yugoslavia	22	14
Italy	5	4	Unknown	10	234

USSR, and countries of Central and South America. Special emphasis is being placed throughout west Asia on the collection of wild *Lens* species. Descriptors are currently being developed, the data will be computerized, and it is intended to produce a complete germ-plasm catalogue in the near future.

Breeding Methodology

Most of the cultivars released throughout the world to date have been derived by selection from germ plasm as opposed to hybridization programs. The degree of further genetic improvement possible by continued selection from local germ plasm is expected to be limited in most countries and major yield advances are only expected to result from selections following hybridization.

Lentils are almost completely self-pollinated and artificial cross-pollination is made difficult by the small and delicate flowers. Crossing under field conditions has thus proved particularly difficult. However, high success rates (over 70%) have been achieved from crosses in greenhouses, where the plants are sown in early autumn and flowering is induced, and synchronized, by creating artificial long-day (18–20 hours) conditions during the winter.

Due to the difficulty in crossing, the major part of the ICARDA lentil improvement work follows modified pedigree or bulk population methods. Efforts, however, are being made to develop techniques for making a large number of crosses under field conditions and thereby enabling the use of population improvement methods, such as modified recurrent selection.

Other breeding methods, including induced mutation and interspecific hybridization, will also be considered, especially for the development of specific characters for which genes are not available in the germ-plasm collection. A number of crosses have already been made with the wild species *Lens orientalis* (considered by some to be conspecific with *L. culinaris*) with the main aim of developing drought resistance. Although the two species cross readily, the work is still at an early stage and the usefulness of these wide crosses in lentil improvement remains to be firmly established.

Broad Bean Breeding

The main objectives of broad bean improvement at ICARDA are to develop a range of materials having different maturities and seed sizes together with the following characteristics:

A high and stable dry seed yield through:

- resistance to the major diseases and pests (including *Orobanche*)
- tolerance to stress conditions (cold, heat, drought, and salinity)
- a more efficient growth habit
- increased autofertility
- reduced flower drop;

A wider adaptability;

Resistance to lodging, pod-shattering, and storage pests;

A high total biological yield;

An improved nutritional value, especially increased protein quantity, together with reduced levels of toxic factors, and maintained protein and cooking qualities.

Although the major emphasis of the program is geared to the development of the crop for dry seed production, some attempts will also be made at genetic improvement for the production of green seed and pods.

Diseases and Pest Resistance

Broad beans are particularly susceptible to damage resulting from disease infection. A wide range of diseases, including pathogens of the root rot/wilt complex, chocolate spot (*Botrytis fabae*), *Ascochyta* blight (*Ascochyta fabae*), brown spot (*Alternaria* sp.), powdery mildew (*Erisyphe polygoni* and *Leveiulla taurica*), rust (*Uromyces fabae*), and several viruses, have been reported to cause serious economic losses. Diseases are in general a greater problem under more humid environments than with irrigated production under dry conditions. In recognition of this, ICARDA's program concentrates its efforts toward the development of resistance (multiple where possible) at a humid Mediterranean coastal site near Lattakia. Few good sources of resistance have so far been discovered and it is expected that emphasis will have to be placed upon building up resistance levels through population improvement methods for the accumulation of minor resistance genes. For certain specific diseases the use of induced mutation may also be considered in the future.

The most important insect pests of broad bean are aphids. Differential reactions to infestations of this pest have been observed in the ICARDA germ-plasm collection and breeders elsewhere have reported useful levels of aphid resistance and demonstrated the value of this in increasing seed yields.

Orobanche is also a major problem in this crop, causing serious losses. Several breeders have reported finding useful levels of resistance and the ICARDA germ-plasm collection is currently being grown in artificially infested pots as a preliminary screening for resistance. As with the development of disease and aphid resistance, it is expected that population improvement methods will prove most useful in raising *Orobanche* resistance levels.

Improved Plant Ideotype

The opportunity for alterations in plant growth habit in broad beans is considerable. Although little work has yet been carried out on the establishment of optimum plant ideotypes for different agroecological conditions, types having a greater degree of determinacy, less top growth, a greater synchronization of flowering, reduced height, a canopy structure allowing increased light penetration, and reduced tillering are being sought in initial improvement efforts. Genes affecting all these characteristics are available and are at present being utilized.

Autofertility

Many broad bean cultivars require tripping of the flowers by bees in order to obtain maximum seed set. In the absence of insect pollinators (which can be caused by spraying against insect pests), seed yield may be reduced. However, because most of the autofertile lines so far discovered have originated outside the Middle East and most of the autofertility work has been carried out in northern Europe, the extent of the problem in this region is not yet clear. A selection pressure in favour of autofertility may be applied through the currently used breeding methods involving selfing through bagging or growing the plants in insect-free cages if artificial tripping is not practiced.

Nutritional Factors

One screening of 511 accessions from the germ-plasm collection at ICARDA has resulted in values in excess of 37% protein (N × 6.25, dry weight basis) being recorded. A population of high protein lines was initiated in 1976 and this will be advanced through recurrent selection with S_1 or S_2 testing. Protein levels of greater than 40% with no concurrent loss in yield are considered possible by some researchers.

The occurrence of the disease favism has been widely reported in the Mediterranean region. Little work has been carried out on this problem, but the presence of two pyrimidines (divicine and isouramil) has been tentatively identified as the cause in genetically susceptible humans. Once the causal agents have been firmly established, screening methods can be developed for their estimation and attempts to breed for nontoxic types can be initiated.

Apart from these two positive nutritional improvement aspects, all advanced lines of lentils and chick-peas as well as broad beans will be routinely screened to ensure that their nutritional and organoleptic properties do not fall below acceptable standards.

Germ Plasm

The ICARDA germ-plasm collection contains only 1300 entries, making it the smallest of the food legume collections retained at the centre (Table 1). Efforts are thus continually being made to expand the collection, germ plasm being especially sought from China (which accounts for two-thirds of the world broad bean production), the Indian subcontinent, eastern Europe, and Central and South America. Germ plasm from northern Europe frequently fails to set seed under the conditions of this region and assistance in the maintenance of this material is currently being sought.

Broad beans are a partially outcrossed species. In the 1975–76 nurseries in Egypt, for example, outcrossing ranged from 11% between rows (spaced at 65 cm) and 33% between plants at one location to over 20% between rows and 40% between plants at another. As a consequence of this high level of natural outcrossing, the germ plasm at ICARDA is maintained in two separate collections: a broad-based collection in which no attempt is made to purify accessions except by subdivision; and a working collection of inbred lines, developed through the selfing of individual plants within the broad-based collection.

Breeding Methodology

As a result of their high degree of outcrossing, ICARDA's approach to breeding broad beans involves considering the crop as both self-pollinated and cross-pollinated.

Development of Pure Lines

Since its initiation at Tel Amara (Lebanon) in 1975, the hybridization program has involved approximately 750 field crosses. Both bulk population and pedigree methods of selection are being followed and compared. No pollination control is normally attempted in early generations; but a separate system, involving the bagging of one or two plants in each progeny row and basing selection of the selfed plants on the performance of the open pollinated family, is currently being tested. This method allows a more rapid increase in homozygosity, enabling the required levels of phenotypic uniformity to be achieved in fewer generations and at the same time permits selection for high autofertility.

There is some evidence of inbreeding depression in broad beans, and selection of inbred lines for high yield and autofertility is thus under way among lines derived from the germ plasm. The best selected lines, together with advanced inbred lines from the hybridization program, will be tested for general combining ability (GCA) and synthetic varieties, composed of inbred lines with high GCA's, will be constituted and evaluated.

Population Improvement

A program of recurrent selection has been started and for this purpose three populations were initiated in 1976–77 and a further three during the present cropping season. Following three or four generations of random intercrossing using honeybees in cages, it is proposed to follow either an S_2 testing (4 seasons, 2 years/cycle) system if recombination can be carried out in the off seasons, or an S_1 system (involving 3 seasons and 2 years/cycle) if recombination using honeybees proves to be only feasible in the main season.

It is proposed to develop a series of mainstream populations based primarily on seed size, maturity, and major adaptation group, and another series of subpopulations for particular characters, such as disease, pest, and *Orobanche* resistance, protein content, etc. When the frequency of desirable genes has increased to a sufficient level in these subpopulations, they will be introgressed with the mainstream ones through intermediate "back-up" populations.

Hybrid bulk populations from the recurrent selection program will be distributed to national programs through the international scheme and will serve as a source of genetic variation for the future development of pure lines as well as a basic population for further improvement by mass selection or for direct release.

Male Sterility

All attempts at crossing between *V. faba* and other *Vicia* species have so far proved unsuccessful. Work on this aspect will be encouraged, however, due to the great potential for improvement by this method; for example, one of the closest relatives of the broad bean, *V. narbonensis*, a wild weedy species found in the region, has been shown to have resistance to a number of diseases and pests, including chocolate spot, *Ascochyta* blight, and certain aphid species.

Chick-Pea Breeding

ICARDA and ICRISAT are working very closely to ensure a good coordination of the activities of their respective chick-pea programs: research at ICARDA is emphasizing the kabuli cultivars, and that at ICRISAT mainly the desi types.

The ICARDA chick-pea improvement program thus focuses on the development of kabuli materials with the following attributes:

A high and stable dry yield through:
- an inherently high yield potential
- tolerance to stress conditions (cold, heat, drought, and salinity)
- resistance to the major diseases and pests (*Ascochyta* blight, root rot/wilt, pod borers, and leaf miners);

A wide adaptation;
A high total biological yield;
Characteristics suited to mechanized harvesting.

Winter Planting

Throughout western Asia, chick-peas are, in general, planted in the spring and grown on residual moisture. It has been well demonstrated that autumn planting could dramatically increase seed yield; however, the greatly increased risk of a severe attack of *Ascochyta* blight normally prevents this practice. An autumn-sown trial at Aleppo in 1978 has shown one entry (NEC 2305) to have a moderate level of resistance to *Ascochyta*; all the other entries in the trial were almost completely destroyed by the disease. This entry produced a yield of over 3 tonnes of seed per hectare as compared to the 950 kg/ha produced by the same variety when spring planted.

At low and medium elevations in the region, much of the material tested to date has shown sufficient cold tolerance to survive the winter and so the prospects for increasing yield through autumn-planted varieties appear promising. Special breeding efforts are, however, planned for the Tabriz site to develop adequate cold tolerance for the plants to survive the extreme winter conditions of the high plateau region.

Disease and Pest Resistance

Ascochyta blight is without doubt the most economically important disease of chick-peas throughout the region. Not only does it prevent the practice of winter planting, but it is also a major yield-limiting factor in the spring-sown crop. Resistance to the disease has been reported, but it is almost exclusively confined to desi cultivars.

A preliminary screening nursery at ICARDA in 1977–78, involving 1200 kabuli cultivars, has revealed about 30 entries with a moderate level of resistance and 7 entries that failed to show any disease symptoms at all. Although it is still necessary to confirm these findings at other locations, the indications that resistant kabuli cultivars can be developed seem promising.

The wild species *C. reticulatum* appears to be a promising source of resistance genes, and one accession has been found to be very highly resistant in seedling tests carried out at ICRISAT.

Improved Plant Type

Several lines originating from the USSR are currently being used as a source of genes for the development of a taller, more erect plant type, which would both facilitate mechanized harvesting and should also result in higher yields at high plant population levels. Some progenies of crosses between these lines and locally adapted types appear very promising in this respect.

The "double podding" condition, where two flowers are produced per peduncle instead of the normal one, is a further character that may be important in increasing the yield potential and stability. Research is also under way on this aspect.

Germ Plasm

A world germ-plasm collection has been developed at ICRISAT and it is planned that a duplicate of this collection will be maintained at ICARDA. A subcollection of kabuli types is also being developed at ICARDA as a working collection.

Breeding Methodology

It is estimated that approximately 75% of the chick-pea production in the main producing areas arises from unselected landraces and, of the improved cultivars that have been released, almost all have originated from selections from this germ-plasm base.

Chick-peas are comparatively easy to cross under field conditions and with the establishment of both the ICRISAT and ICARDA programs, large-scale crossing can be undertaken, allowing the development of population improvement methods in addition to the pedigree or bulk methods traditionally used in chick-pea breeding.

One approach currently being followed is the introgression of kabuli and desi germ plasm. These two groups have been separated for many hundreds of years and it is therefore probable that the genetic divergences between them are appreciable. The introduction of new "exotic" genes into locally adapted cultivars may thus result in significant yield advances, especially in the improvement of kabuli types, for which the available germ-plasm base is considerably narrower. There is some evidence, however, that coadaptation is important in chick-peas and that wide crossing tends to break up coadapted gene blocks. If this is the case, then backcrossing to the adapted parent would help to prevent excessive adaptation breakdown, while at the same time giving the added advantage of increasing the frequency of genes for acceptable seed characters (the small, coloured seeds of the desi types being unacceptable throughout most of the Middle East). Work on this scheme was started in 1975 with 158 kabuli × desi crosses, and 217 back crosses and three-way crosses were made in 1977. The effectiveness of this method, however, still awaits a more comprehensive evaluation.

Some Agronomic and Physiological Aspects of the Important Food Legume Crops in West Asia

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The extent to which a plant can harness the natural resources of solar radiation, carbon dioxide, water, and other inorganic nutrients available to it in the production of yield is dependent upon its genetic composition. The genetic control of yield is achieved through regulation of the morphological structure of the plant and its physiological functioning. The genetic constitution of the plant thus determines its potential yielding ability, but the degree to which this potential is realized depends to a large extent on the environment in which it grows. Because the crop environment can be partly regulated by agronomic manipulations, the achievement of high yields, which is one of the main objectives of crop improvement work, demands that aspects of agronomic management be given active consideration alongside the genetic alteration of plant structure and functioning.

Lentils (*Lens culinaris*), chick-peas (*Cicer arietinum*), and broad beans (*Vicia faba*) are the three food legume crops of major importance to the agriculture of West Asia and North Africa. Their respective average productivity is reported to be 1068, 950, and 1872 kg/ha in the Near East and even lower in the Far East and Africa, as against maximum yields of 3500, 4400, and 7500 kg/ha, respectively, reported from experimentation. Quite a substantial part of this apparent gap between the potentially realizable and actually realized yield may be attributed to inadequate agronomic management.

With this background, the present paper briefly reviews the current state of knowledge on the agronomy and production physiology of the three food legumes with the aim of highlighting the importance of the various factors that affect yield and identifying areas requiring further research emphasis in the future.

Environmental Conditions

The temperature optima for the growth of lentils, chick-peas, and broad beans lies between 10 and 30 °C and the crops will thus grow at all locations where altitude and latitude permit these temperature ranges. All three crops, for instance, are grown extensively at low elevations between latitudes 15 and 40°N; and chick-peas are also produced between 0 and 15°N, but at higher elevations to meet the low temperature requirements; and broad beans may be cultivated up to 60°N at low altitudes and in close proximity to the sea.

Chick-peas, lentils, and to some extent also broad beans are subject to decreasing temperatures and day lengths immediately after planting in India, Pakistan, and some parts of North Africa, whereas they experience increasing temperatures and day length when grown in Iran, Syria, Jordan, Lebanon, Turkey, Italy, and Spain.

The soil moisture availability and stresses under which these crops are produced also vary considerably throughout the region, with the differences in rainfall pattern (and irrigation) and thermal regimes experienced. They are raised on conserved soil moisture in the Indian subcontinent and in parts of Iran and Turkey, while production in Egypt and Sudan is almost entirely irrigated. In Syria, Lebanon, Jordan, and adjoining areas, broad beans are grown exclusively under irrigation, except at high rainfall coastal locations, whereas chick-peas and lentils are produced mainly under rainfed conditions, the former on residual moisture after the winter rains and the latter during the rains, but exposed to the desiccating atmosphere and moisture stress during flowering and crop maturity.

The environmental conditions under which these crops are produced can thus be seen to be very varied with respect to many aspects.

Lentils

Agronomic Requirements

Emergence

Lentils are ecologically well adapted to cooler environments, but are adversely affected by long and intense periods of frost. They are therefore grown as winter crops only in areas experiencing mild winters, and where winters are severe are usually spring sown. The optimum temperature for germination ranges between 15 and 25 °C, the rate of emergence being slower at the lower temperatures. Sowing at a depth of 4–5 cm has been found to ensure rapid emergence and a better dry matter production than either shallower or deeper planting. Greater delays in emergence have been observed with deeper plantings as soil temperature decreases and small-seeded cultivars appear to be more sensitive to deep planting than the larger ones. Varietal differences in the rate of emergence have been noted in preliminary studies at the ICARDA site in Syria during the 1977–78 season.

Date of Planting

The performance of lentils is affected markedly by planting date, the optimum time varying between locations. Under Indian conditions, the second half of October has been found to be the best time, but the highest yields achieved in Egypt have been obtained from planting in the first half of November. The optimum planting date in Karaj (Iran) was found to be in mid-March, but at higher elevations, planting generally takes place in late April or early May.

Delayed plantings invariably result in conspicuous yield reductions as a result of reduced vegetative growth and the early termination of growth and onset of senescence due to the rapid temperature rises experienced during the reproductive phase.

Plant Population

Responses of lentils to planting density have been highly variable and depend largely upon the growing conditions and the cultivar type. Many common cultivars exhibit a high degree of plasticity and therefore little yield differences have been obtained with large variations in sowing rate, particularly under conditions of adequate moisture supply and high soil fertility. However, a general trend for yield to increase with sowing rate has been observed by some researchers, a density of about 300–450 seeds per m^2 giving the highest yields. Such densities may be obtained with seeds spaced at 1.5–3 cm in rows 15–30 cm apart. Under conditions allowing only restricted vegetative growth (e.g., late sowing; under inadequate moisture conditions) or with cultivars possessing a lesser plasticity, narrower spacings and higher seed rates are recommended. This will enable the development of a closed leaf canopy, permitting optimum interception of incident radiation and resulting in higher yields. Based on calculations from seed density studies and a series of seed rate trials, rates of 60–80 kg/ha for small-seeded types and 160–200 kg/ha for the large-seeded varieties appear to be optimum for dryland areas.

Farmers over much of the region use higher seed rates than these, broadcast the seed, and then mix it into the soil with a country plough. This process converts the seedbed into a series of ridges and furrows and concentrates the seed in bands at the top of the ridges. Such a situation gives a suboptimal utilization of the space available and results in a high level of interplant competition. To avoid this yield-limiting problem, seeds may be drilled or planted into rows about 22.5–30 cm apart, without any subsequent cultivation.

Fertilizer Requirement

A lentil crop yielding 2 tonnes of grain per hectare may take up in the process about

95–100 kg of nitrogen per hectare. Under Egyptian conditions it has been reported that about 77% of this requirement could be satisfied through symbiotic nitrogen fixation. However, this level of performance will only be possible with very effective fixation. The need for inoculation with effective strains of *Rhizobium leguminosarum* has thus been emphasized and a consideration of host variety/rhizobium specificity is an important factor in such inoculations, as significant specificity has been recorded. Several studies have shown that applications of 20–30 kg N/ha are necessary as a starter to ensure the adequate nitrogen nutrition of the crop, despite the large contribution made by rhizobial nitrogen fixation.

Farmyard manure has been found to have a positive effect on the performance of lentils and is commonly recommended for lentil production in Pakistan.

The soils of many lentil-growing areas are characterized by a low available phosphorus status and economic responses have been obtained from phosphate application in India, Pakistan, Iran, Egypt, Syria, and Greece. The optimum rate varies from 40 to 100 kg P_2O_5 per hectare, depending upon the fertility status and phosphate fixation capacity of the soil. Studies on high pH, low phosphorus soils of Syria have revealed that an available P status of 4 ppm was required in the soil during periods receiving normal levels of rainfall, but that when precipitation was scarce, a range of 7–9 ppm was necessary for the highest yields. This work highlights the importance of phosphate fertilization in lentil crops, particularly during years of suboptimal rainfall.

In contrast to phosphate, positive responses to potassium application have been few. Significant yield increases have been obtained with applications of 22 kg/ha of K_2O in 2 years out of 3 on a sandy loam soil in the Punjab of India, but no responses have been obtained in Iran or Sudan. An improvement in the cooking quality of lentils has, however, been reported from K applications to the crop raised in pots and adequately supplied with other macro and microplant nutrients.

Studies on the response of lentils to micronutrient applications have, to date, been limited. Micronutrient deficiency problems are, however, likely to be encountered in the crop, because lentils are frequently grown under edaphic conditions where the availability of such nutrients is likely to be restricted. Lentils show a high susceptibility to zinc deficiency (fairly widespread on paddy rice soils in India and Pakistan) and, although varietal differences have been observed, most of the varieties show yield improvements from soil applications of 10–15 kg/ha of zinc sulfate or a foliar spray of 5 kg/ha of the chemical when deficiency symptoms are first evident. Experiments have shown the crop to exhibit deficiency symptoms when the P:Zn ratio was higher than 400 and the Fe:Zn ratio higher than 11 in the whole shoot. It has also been found that application of zinc at the rate of 5 ppm increased the survival of lentil rhizobia in the rhizosphere, decreased the P:Zn and Fe:Zn ratios in the lentil shoots, and increased the number, dry weight, and leg-hemoglobin content of root nodules, resulting in increased nitrogen fixation and dry matter yields in zinc-deficient soils. Positive responses have been obtained to molybdenum application in Bulgaria, increases of 15.5 and 17.5% in seed yield being obtained by soaking the lentil seed in ammonium molybdate solutions designed to provide an equivalent of 50 and 100 g Mo/ha. Although some workers failed to achieve a response through foliar spraying, others have reported increased yields, crude protein contents, and phosphate uptake through sprays of the chemical at concentrations of 0.01, 0.02, and 0.04% and a rate of 60 litres/ha.

Water Management

Under adequate moisture conditions, lentils are known to use water at least as luxuriously as cereal crops. The transpiration ratio appears to vary with region and variety, ranging between 200 and 500 in the humid region and from 800 to 1500 in the semi-arid region. Growth chamber studies have revealed that leaf area and dry matter production increase with increasing irrigation frequency, and positive responses have also been obtained in the field. The crop is, however, very sensitive to overwatering and yield reductions will occur if irrigation is excessive. Flowering appears to be a critical growth stage for water supply and delaying irrigation beyond this stage has been shown to cause yield reductions.

In general, lentils, however, are grown as a rainfed crop. In the Indian subcontinent, where they are produced on residual moisture, the moisture conserved from late rains in the monsoon season determines crop performance, whereas in the Mediterranean-type climate the yield depends largely upon the rains received during the period December to March. In both cases irrigation is rare.

Weed Control

Morphologically lentils are at a disadvantage with respect to competition with weeds, and yield reductions of up to 75% have been reported as a result of weed infestations. Weed competition is most serious in winter crops between 30 and 60 days after crop emergence in areas with mild winters and between 60 and 90 days after emergence where the winter conditions are more severe. Mechanical weed control during this period has proved an effective and economical method under Indian conditions and has generally been superior to the use of herbicides. Results of tests on several herbicides applied at different crop stages have indicated some promising chemical control methods: trifluralin, when used as a preplant-incorporated herbicide, has proved good under adequate moisture conditions although tolerance to this chemical is generally low in the crop; and linuron, prometryne, and dosanex have shown promise as preemergence herbicides. Considerably more herbicide screening, especially on the basis of toxicity to weeds and crop tolerance, is now necessary to evolve appropriate chemical weed control for the dryland production of lentils.

Harvesting

The conventional method of lentil harvesting involves the hand pulling of plants before they are completely dry to avoid pod shattering. However, considerable yield losses still occur, particularly during the gathering and transporting of the plants after they have been field dried in the sun.

Mechanical harvesting, which is already practiced in the United States, is becoming an increasingly urgent consideration in West Asia as a result of the declining availability and consequently increasing cost of hand labour at harvesting. However, the generally short plant stature and susceptibility to lodging evident in currently grown varieties poses a great problem to the introduction of this technology. The development of taller varieties with stronger stems is thus an obvious way to facilitate mechanical harvesting and in turn reduce harvesting losses. Experiments have indicated that some height increase may be obtained in lentil by sprays of gibberellic acid, but more studies on this aspect are necessary before it could be put into practical use. Investigations have shown that *Camerlina* spp. and yellow mustard in mixture with lentils help to prevent lodging and facilitate harvesting, but such a technique appears to have only limited applicability.

Physiological Aspects

Although lentils have frequently been used in biochemical studies, work on their physiology has been limited. Additional information on the physiological aspects of the crop will assist in understanding the reasons for the adaptability of existing cultivars to rather narrow agroecological regions and in the development of genotypes with a wider adaptability.

Photoperiodic and Vernalization Requirements

Lentils are sensitive to photoperiodic conditions and are classed as "long day" plants. Genotypes may, however, differ, some showing "quantitative" requirements whereas others behave as "qualitative long day" plants.

Vernalization studies involving the exposure of soaked seeds to a temperature of 6 °C for about 5 weeks have shown that lentils respond to vernalization by a hastening of flowering and a reduction of the period of vegetative growth.

Salt, Drought, and Heat Tolerance

Stress from salinity, drought, and heat causes a considerable reduction in the productivity of lentil crops. This stress varies appreciably with season and climate and the development of varieties tolerant to these conditions may lead to real increases in the yield stability.

A 50% reduction in the germination of lentils was observed at a soil conductivity of 20 mmhos/cm, whereas yield reductions of 50% occurred at 3.9 mmhos/cm conductivity level. Investigations on two varieties have shown the salt tolerance limit to lie between 8.4 and 13.1 mmhos/cm conductivity and conspicuous reductions in dry matter yield to occur beyond 5.0 mmhos/cm. The cultivar Large Blonde was found to tolerate salinity better than Anicia, the other cultivar tested.

Differences in tolerance to drought have also been observed between cultivars: white lentils from Syria appear to be more tolerant than the red lentils from Egypt; and evaluations of 100 genotypes near Sofia (Bulgaria) have indicated that large-seeded types, with their longer growing period, are less tolerant to drought than small-seeded cultivars.

Canopy Development and Photosynthesis

The mean crop growth rate is very low in the early vegetative phase, particularly at low temperatures. However, there are indications that genetic differences exist in the rate of canopy development and dry matter production under such conditions. Total dry matter production and grain yield have been found to be very highly correlated with the degree of interception of photosynthetically active radiation during the pod-filling stage, a closed canopy, permitting 90% interception of incident radiation at the flowering period, giving the highest yields. Canopy closure is dependent upon the branching pattern and leaf area development. Genotypes can be seen to differ appreciably in both these characters and in the degree to which they are expressed in differing environments. Genotypic differences have also been observed in the photosynthetic rate and the partitioning of dry matter into different components of yield. Such a variability means that the potential for evolving more productive genotypes, in terms of dry matter as well as economic yield, is considerable.

Growth Regulation

Seed treatment with growth regulators, such as indoleacetic acid and indolebutyric acid have been demonstrated as affecting the rate of seedling establishment and early growth. The role of growth regulators in modifying the canopy structure and productivity of lentil has also been investigated. Under conditions of late planting, permitting restricted plant growth, significant increases in lentil yield have been recorded following a foliar spray of a 20-ppm solution of the sodium salt of naphthyl acetic acid 50 days after planting. High rates of applications of 2,3,5-Triiodobenzoic acid, however, resulted in reduced yields in one lentil cultivar through the production of an intertwined canopy. The role of growth regulators and antitranspirants on drought tolerance and water use economy still remains to be established.

Chick-peas

Agronomic Requirements

A general review of the agronomic requirements of chick-peas has previously been carried out as have agronomic studies under Indian conditions (Saxena and Yadav 1976; Van der Maesen 1972). The present coverage is therefore mainly restricted to work in West Asia and North Africa.

Planting Date

Chick-peas produced in the region may be planted from early winter to late spring, depending upon the location. It has been observed in studies of plantings from 16 August to 20 October that delayed sowing results in reduced growing, preflowering and flowering periods, and a considerable depression of plant development, leading to drastically reduced yields. Studies in Sudan have established the optimum planting time as late November to early December; earlier as well as later plantings result in appreciable yield reductions. At lower elevations in Iran, the highest yields have been obtained from October plantings, but at higher elevations autumn plantings have led to winter injury and thus chick-peas are generally spring sown, early April proving to be the best time in Karaj and late April–early May being the optimum at Tabriz. In general, the winter temperatures over much of the Mediterranean region are not sufficiently severe to cause damage to autumn-sown chick-peas. However, most farmers still adhere to spring plantings and the subsequent exposure to moisture stress and high temperatures during the early phase of reproductive growth, which result in reduced yields. This is primarily because, despite the higher yields that can be obtained from autumn planting, the incidence and destructiveness of *Ascochyta* blight is considerably increased and total crop loss often results. The development of genotypes suitable for winter planting (i.e., with cold tolerance and tolerance or resistance to *Ascochyta* blight) will thus fulfill a great need and enable very great yield increases in this crop.

Plant Population

Optimum plant population appears to depend very much on growing conditions, especially moisture supply. Investigations undertaken over a 3-year period in Karaj (Iran) with irrigated chick-peas have shown that yield increases with plant population, the highest yields being obtained with 0.5 million plants per hectare. Subsequent studies at Tabriz have confirmed this trend under irrigated conditions and have indicated lower populations (about 0.248 million plants/ha) to give the highest yield in rainfed crops. Information is currently required on optimum plant populations and planting geometry for genotypes with different growth habits and planted at different seasons in the Mediterranean-type climates.

Fertilizer Use

The removal of plant nutrients by a chick-pea crop yielding about 3 tonnes of grain and 4.5 tonnes of straw per ha has been estimated to be approximately 144 kg N, 31 kg P_2O_5 per ha. It has also been estimated that 100 kg N/ha, or 77% of the total nitrogen content of the crop, is annually supplied through symbiotic fixation under Egyptian conditions. The contribution of symbiosis to total nitrogen yield in the crop probably varies with host genotype, rhizobial strain, and environmental conditions. Under favourable conditions, therefore, symbiotic fixation could account for almost all of the crops' nitrogen requirements, as was probably the case in studies carried out in India and Iran as part of the Regional Pulse Improvement Project, which showed no large-scale responses to nitrogen fertilization. However, other experiments in Sudan have shown positive responses to increasing applications of nitrogen (up to 120 kg/ha in irrigated crops). Split applications (one-half at sowing and one-half at flowering) were found to be best in these cases, particularly at intermediate levels of fertilization (80 kg/ha). Poor nitrogen status of the soils and the lack of nodulation (possibly due to salinity) were considered to be responsible for this positive response and the need for inoculation with effective strains of *Rhizobia* was emphasized under such conditions. The use of solid inoculant in the furrow, rather than the slurry inoculation of the seeds after treatment with Cerasan fungicide, has been recommended as the key to good nodulation.

No response to the application of either phosphorus or potassium could be obtained in experiments at Karaj, and investigations on phosphorus-deficient soils at ICRISAT (India) have also failed to obtain yield increases from phosphorus applications. The reasons for this apparent lack of response must be investigated. Perhaps this will lead to a revision of the standards of deficiency and sufficiency levels and the development of improved methods of assessing the availability status of phosphorus in soils. Chick-peas are known to have a high sulfur requirement and responses to applications of sulphur also warrant future studies.

Only limited studies have been conducted on crop response to micronutrients to date. Iron deficiency symptoms have been observed in some chick-pea cultivars when grown on highly calcareous soils in Lebanon and Syria, although the majority of the locally grown cultivars showed no such problems. This deficiency may be easily corrected by foliar sprays of a 0.5% solution of ferrous sulfate, but care should be taken to ensure that the trait for more efficient iron utilization is retained in genotypes being bred for calcareous soils. Zinc deficiency has also been observed in chick-peas and varietal differences in susceptibility have been recorded and may be used in breeding programs, although the deficiency can be corrected by spraying zinc sulfate (0.5% solution).

Water Use

The water requirement (i.e. transpiration ratio) of chick-peas is reportedly as high as 1000. In most parts of the region this requirement must be met from moisture conserved in the soil profile from the preceding rainy season. If this conserved moisture is insufficient to the needs, the crop responds well to supplementary irrigation. Studies at Shiraz (Iran) have shown a 6-day irrigation interval to give yields almost twice as great as with irrigations every 9 days. A higher irrigation efficiency was obtained with basin irrigation (45.4%) as opposed to furrow irrigation (35.5%), although this had no effect upon yield. The greatest yield response in work at Karaj has been achieved by irrigation at the prebloom stage every time the soil moisture fell to 33% of field capacity, and during the period after full bloom every time the level reached 66% of field capacity. Field experiments conducted in Sudan have given the best results with a 14-day irrigation interval; more or less frequent irrigations depress the yields.

Urgently needed at the present time are agronomic methods designed to increase the conservation of moisture in the soil profile in the preplanting period and to reduce its loss during crop growth. Such methods will greatly increase the efficiency of the use of moisture received through precipitation.

Weed Control

Although better competitors than lentils, chick-peas also suffer from weed competition. Screening for suitable herbicide control measures is currently under way at ICARDA and detailed studies are now required to devise an effective system of weed management through a combination of cultural and chemical methods.

Harvesting

The need for mechanization of harvesting is widely recognized in this crop, as in lentils, throughout the region. The effects of various cultural practices on harvest loss in chick-peas must be investigated and breeding work should emphasize the development of taller plants with a more upright growth habit.

Physiological Aspects

Germination

Although germination may be obtained at temperatures as low as 10 °C and as high as 40 °C, the optimum soil temperature for germination appears to lie between 25 and 35 °C. At lower temperatures the time lag before germination increases; with decreasing temperatures the crop emergence is decreased; and no emergence occurs at soil temperatures above 44 °C.

Photoperiodic and Vernalization Responses

Chick-peas seem to be sensitive to photoperiod and to respond to vernalization. This may be partly responsible for the observed adaptability of genotypes to rather specific locations. Although chick-peas have been generally found to be "long day" plants, some genotypes appear to flower under day lengths as low as 8 hours. Such genotypes may be less sensitive to photoperiod and thus have considerable potential for use in breeding efforts designed at achieving wider adaptability. Flower bud initiation and flower development have been shown to be hastened by long day conditions and the effect of vernalization to complement this.

Salinity Tolerance

Chick-peas are highly sensitive to salinity, irrigation with water of a conductivity of 10 mmhos/cm reducing yield by as much as 55%. The development of salt-tolerant genotypes is thus a priority consideration for areas where the crop is grown under irrigation and the water tends to be brackish. In addition, because root nodule function seems relatively insensitive to salinity after establishment, special inoculation methods should be developed to enable successful establishment of *Rhizobia* with the host roots under saline conditions.

Drought, Heat, and Frost Tolerance

As most chick-peas are grown on conserved moisture, the rooting pattern may be an important determinant of crop performance. Genotypic differences in rooting pattern are evident and such differences may thus be of use in the development of varieties with some tolerance to drought and hence greater yield stability. However, the effective use of this character in varietal improvement work requires that a quick technique be developed for screening genotypes for their potential root growth.

Tolerance to high temperature during reproductive growth would also be a very desirable character for crop production in the drier areas. The double pod character (two pods per peduncle rather than the usual one) has been reported to express itself well under the adverse conditions that tend to shorten the flowering period. This character may prove very useful in the breeding of more stable varieties for production under these conditions.

Frost tolerance is also a desirable character for the development of high-yielding varieties for the high elevation plateau areas of the region, where spells of frosty weather are likely to occur during seedling establishment and early vegetative growth.

Photosynthesis

Chick-peas possess considerable genetic variation in their photosynthetic rates. The rate of photosynthesis normally decreases sharply with the onset of flowering, although varietal differences in this respect were also conspicuous.

Photorespiration is responsible for considerable losses of photosynthate and the temperature conditions under which reproductive growth takes place in the region tend to increase this process and thus reduce net carbon gain by the crop. The identification of genotypic differences for a more efficient photosynthetic system, reduced photorespiration, and higher nitrogenase activity during reproductive growth should thus greatly increase the potential for developing more productive cultivars.

It has been shown in some cultivars that photosynthesis in the pod wall may make a significant contribution to the carbon pool in the developing seed. Although studies have shown that the "exposed pod" character does not seem to confer an advantage to a genotype, its importance needs to be further examined with a wider range of genotypes and environmental conditions before any firm conclusions can be drawn.

Broad Beans

Agronomic Aspects

Agronomic studies of the broad bean crop have been carried out fairly extensively in Egypt and Sudan where production is under irrigation, but little published information is available from other parts of the region.

Date of Planting

Experiments conducted over a 3-year period and at a number of different locations in Egypt have revealed that 15 October–1 November is the best planting date for broad beans. Similar and subsequent studies with improved varieties in Sudan have confirmed these findings. Varietal differences in yield reduction with delay in planting were conspicuous.

Plant Population

Yield per unit area has been reported to reach a maximum at a plant density of 35–45 plants/m^2 in winter types and at 67 plants/m^2 in spring cultivars. It has also been found that, for a given density, alterations in the between-row distance had little influence on plant development. Studies in Sudan have shown that yield increases with seed rate between 83 and 166 kg/ha, but that seed rates beyond 332 kg/ha caused yield reductions. Within this range it appears that closer row spacings and higher plant populations tended to result in higher yields; the plants, however, showed considerable compensatory mechanisms between their yield components, so that large variations in density caused relatively small yield differences. Similar results have been obtained from investigations in Egypt, where varietal and locational differences have also been detected; a row spacing of 30 cm and a hill spacing of 15 cm (with two plants per hill) gave much greater yield increases over spacings of 60 and 20–25 cm, respectively, in Middle Egypt than in the Nile Delta region. Egyptian studies have established the optima for seed rate at 140–180 kg/ha and studies in Ethiopia at a field spacing of 20 × 15 cm.

Fertilizer Use

Broad bean is known to fix more atmospheric nitrogen than either lentils or chick-peas. Estimates of N fixation under Egyptian conditions are about 135 kg/ha, which may account for approximately 70% of the total N content of the plant. The contribution of symbiotic nitrogen to total plant nitrogen may vary with soil N content and rates of fertilizer N application. Positive responses have been obtained to inoculations with suitable rhizobial strains. Broad bean yields have been increased by 10–12% with the application of 18 kg of inorganic N/ha, but in these studies no further response was obtained with applications over 36 kg/ha. However, good responses have been found from 42 kg N/ha applications in Sudan, particularly when fertilization was delayed until 2 months after planting or split into three dressings (33% at planting, 33% after 1 month, and 33% after 2 months).

Conspicuous responses to phosphorus applications have been observed in Egypt and rates of 72 kg P_2O_5/ha are recommended. Foliar application has been reported as better than applying the fertilizer to the soil in northern Sudan.

Positive responses to fertilization with potassium have been found outside the region but no reports of responses are available from within West Asia and North Africa. The favourable effect of potassium upon nodulation and symbiotic nitrogen fixation is well known and there is thus a need to study the importance of fertilization with this nutrient chemical in broad bean production in the region.

Studies on crop response to micronutrient applications are also limited and little information is available from the region. However, an application of molybdenum has been shown to improve the symbiotic nitrogen fixation and nitrogen nutrition of broad beans on a soil containing 0.18–0.29 mg Mo/kg.

Water Management

The transpiration ratio of broad beans has been reported to vary with climatic conditions, being 282 in Germany as against 736 in Colorado (USA) and, in both cases, higher than the corresponding values for wheat.

Water stress has been shown to reduce the absolute growth rate of leaf area and thus overall vegetative growth in broad beans. This effect is also extended into a significant reduction of grain yield. In addition, nitrogen fixation appears to be very highly correlated with the available moisture content of the soil. Studies have illustrated that the yield of broad beans is 80% higher under a "wet" regime (involving nine irrigations in both the vegetative and reproductive phases) than under a "dry" regime (with only six irrigations). These studies also revealed that it was better to maintain a wet regime during vegetative growth followed by a dry one from flowering to pod development, rather than vice-versa, but they were unable to pinpoint the critical stages very precisely. No significant responses to irrigation were obtained in Lower Egypt because of the rainfall, but between four and six irrigations were needed for good crop performance in the drier areas of Middle and Upper Egypt. Higher irrigation frequencies have also been reported to suppress infection by the very damaging parasitic weed *Orobanche*.

Excessive water supply can damage the broad bean crop. It is known, for example, that a water table at 5 cm below the soil surface can result in rotting of the seeds. The water management of this crop must thus be very good to prevent either prolonged periods of moisture stress or water logging.

Physiological Aspects

Germination

Germination rate has been found to increase as night temperature is raised from 5 to 20 °C with a constant daytime temperature of 20 °C. Highest seed yields were obtained when the night temperature was held at 10 °C.

Photoperiodic and Vernalization Response

Broad bean cultivars appear to behave either as long day or day neutral plants and showed some response to vernalization. Quantitative long day responses have been observed and flower initiation may be hastened by increasing the day length from 6 to 16 hours or a brief exposure of the plant to low temperatures (10 °C proving better than 4 °C in this respect). Such low temperature treatment may serve to overcome a reaction inhibitory to flower initiation that has been observed at temperatures above 14 °C during the flower initiation period. Vernalization of broad bean seed has also been found to be possible on the mother plant itself and this treatment leads to more rapid development of plants derived from treated seed.

Plant Ideotype

Most of the conventional varieties of broad bean are "top heavy" and tend to lodge under favourable growing conditions. It appears that only a fraction of the total leaf canopy is responsible for the interception of most of the incident light and therefore there is considerable mutual shading, a theory well borne out by the observation that precision planting gives much higher yields than normal drilling and that seed number and seed yield per plant increases linearly with the increase in available space from 200 to 500 cm^2 per plant. The development of a more open canopy with a terminal bud culminating in an inflorescence has been suggested as a means to evolve a more efficient plant type. Investigations are currently under way into this aspect at several locations using a topless mutant from the variety Primus, developed in Sweden.

Of the different contributory characters to yield in broad bean, it has been reported that the number of pods/plant was most important and that this was regulated more by the number of pods/node than by the number of nodes forming pods. An analysis of the relations between number of podded nodes/plant, pods/podded node, seeds/pod, and seed weight has revealed slightly negative correlations or no relations at all. From these studies it was concluded that the number of podded nodes/plant was the most important yield-determining character, although under adverse conditions the reduction in this character could be compensated for by an increase in the number of pods/node. There is an obvious need for more detailed examination of the role of these characters as they affect yield under conditions of scarce moisture supply and heat stress.

In general, the varieties grown in the Mediterranean area are more branched than those cultivars grown in Europe. This character may be important in stabilizing the yield of the crop in dry areas and requires further investigation.

Flower Drop

The loss of flowers and young pods may be substantial in broad beans: it has been reported, for example, that 86.7% and 93.7% of the buds produced by the varieties Baladi and Giza 1 were lost from flower and young pod drop. Dropping apparently starts at the lower internodes and progresses upward and intra- and interinflorescence competition between the young pods leads to drops from the nonpreferred positions. This problem may be compounded in the indeterminate types, where vegetative growth continues for a long period and overlaps with reproductive growth. It appears that the younger fruits have to overcome a lag phase and only when sufficient photosynthates are available can more young fruits begin to develop. It should thus be possible to increase yield by reducing competition between vegetative and reproductive growth through breeding, treatment with growth regulators, or detopping. Other possible reasons have also been suggested for flower drop apart from the deficiency of assimilates for the developing reproductive sink. These include: nitrogen supply; hormonal factors; gaseous exchange; temperature and humidity in the canopy; mineral nutrient supply; and soil moisture. One or more of these factors may well be responsible for flower shedding and it is thus necessary to identify the prime causes to permit eventual regulation of fruit set and yield.

The productivity of the three major legume crops produced in West Asia can thus be seen to be considerably affected by a very large number of physiological and agronomic factors, which limit both the yield potential and the degree to which this genetic potential is expressed in the production of the crops. A deeper and more comprehensive understanding of the physiological mechanisms that enable survival and determine yielding ability under the harsh dryland conditions of the region will provide a much more solid and logical base to breeding efforts designed to produce cultivars better able to exploit these environments. In addition, to ensure that these cultivars actually result in the improved yield for which they have the potential under field conditions, studies of crop agronomy must figure very highly in the overall strategy for their improvement.

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The Role of Symbiotic Nitrogen Fixation in Food Legume Production

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Food legumes represent the most economically available source of protein for human consumption, and many of the legumes compare very favourably with animal protein in relation to quality and amino acid content. Despite the increasing use of nitrogenous fertilizers in agriculture (ca. 36.5 million tonnes in 1973), estimates suggest that throughout the world, biological nitrogen fixation contributes at least five times as much nitrogen to the soil as artificial fertilization. Hence, in addition to supplying the nutritional needs of a large proportion of the world's population, legumes, through their symbiotic relation with *Rhizobium* bacteria, which are the perhaps most important contributors to biological nitrogen fixation, provide the mainstay for the agriculture of the world.

Biologically fixed nitrogen has several advantages over nitrogen supplied by chemical fertilization. Much of a chemical fertilizer applied to the soil is made unavailable to plants through leaching or combination into insoluble compounds. The "efficiency value" of sulfate of ammonia, for example, is about 30–60%. However, as symbiotically fixed nitrogen is in the organic form, it becomes available more slowly and in a different form, resulting in little loss of nitrogen. For this reason a symbiotic fixation of 100 kg of nitrogen is equivalent to an effective application of considerably more than 100 kg of nitrogen as sulfate of ammonia. In addition to this obvious advantage, chemical fertilizers are very costly to produce and transport, and many farmers in developing countries cannot afford to apply effective amounts of these fertilizers even to such crops as cereals, which have high net rates of return. Legume crops, with their generally low returns, are thus rarely able to justify application of inorganic fertilizers in these areas. However, the nitrogen-fixing ability of *Rhizobia*, in association with legume plants, provides an effective solution to this problem. Our aim, in promoting the cultivation of food legumes in the developing world, should thus be to make as much use of this important attribute as possible in the maximization of yields.

The amount of nitrogen fixed and the production of dry matter or grain yield vary considerably as a result of genotypic and locational differences and the errors inherent in making such estimations. Estimations of the quantities of nitrogen fixed by different food legumes in different locations across the world (Table 1) show a wide range in almost all crops. This variation may reflect differences in varieties, environments, or husbandry, and immediately suggests the large potential for improvements in nitrogen fixation and hence in overall crop yield. Studies on Desi-type chick-peas in India have shown that the application of 150 kg of nitrogen per hectare can increase grain yield by 62% over the control, whereas rhizobial inoculation led to a 65% increase.

Symbiotic nitrogen fixation is considerably affected by the various environmental factors outlined in Fig. 1.

A study of nitrogen fixation at different temperatures in chick-peas has shown that, in general, *Rhizobia* will fix more atmospheric nitrogen at a root temperature of 23 °C than at 30 °C. However, different strains of *Rhizobia* appear to vary in their tolerance to temperature, so that the strain Ca-2 fixed 60% as much N_2 at 30 °C as at 23 °C, whereas the strain 27A2 fixed only 17%. This resulted in Ca-2 fixing four times as much nitrogen as 27A2 at 30 °C, although the differences in fixation at 23 °C were not appreciable. Similarly one can predict the occurrence of cold-tolerant *Rhizobium* strains as well.

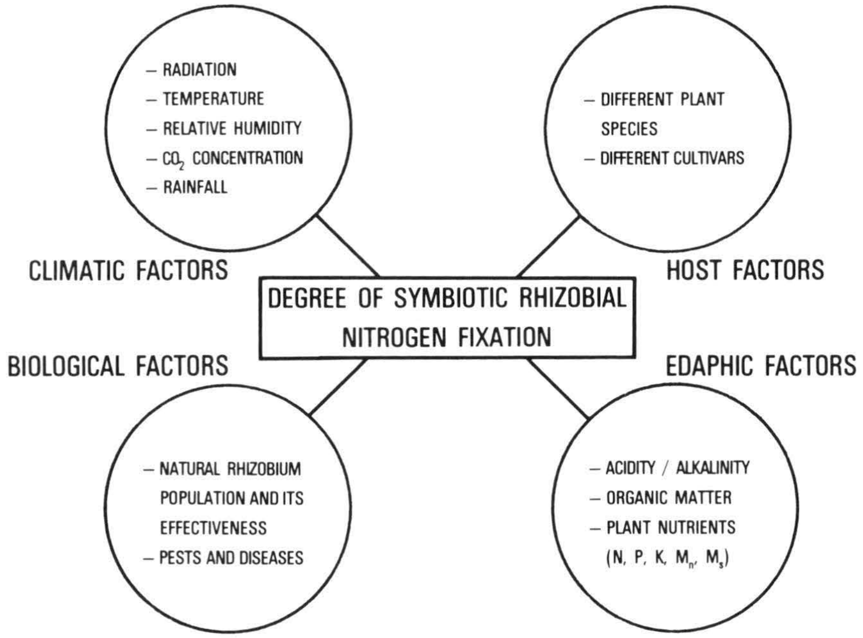

Fig. 1. Various environmental factors affecting symbiotic nitrogen fixation.

The salinity of soils has also been shown to affect different strains of *Rhizobia* in different ways: a strain isolated from saline soil in India produced more nodules and a greater nodule mass than other strains when tested in saline soils in northern Sudan. There is, as yet, however, no indication of whether this advantage will also be reflected in an increased grain yield.

There is considerable variability in both the response of different cultivars of legume species (i.e., chick-peas) to inoculation with a single strain of *Rhizobium* and the response of different strains of *Rhizobia* when inoculated into the same chick-pea variety. This is illustrated in Fig. 2 and 3, which show differences in both nodule number and weight of nodule tissue between strains and varieties. Such variation suggests that *Rhizobia* possesses a reasonable degree of host specificity, and means that one can, by experimentation, select a suitably good *Rhizobium* strain for a given improved cultivar and, in view of the varying responses of strains to growing conditions, for a given range of environment.

Microbiology work at ICARDA commenced in February 1978 and special emphasis is being given in these early stages to studies of nodulation on chick-peas, as this is a

TABLE 1. Estimates of nitrogen fixation by some food legumes.[a]

Crop			
Species	Common name	Nitrogen fixation range (*kg/ha*)	No. estimates
Cicer arietinum	Chick-pea	73–103	3
Lens culinaris	Lentil	83–114	2
Vicia faba	Broad bean	45–552	4
Pisum sativum	Dry pea	52– 77	1
Glycine max	Soybean	64–206	3
Vigna unguiculata	Cowpea	73–240	3
Arachis hypogea	Ground nut	72–240	3

[a]Assembled from various sources by Nutman (1976) and Ayanaba (1977).

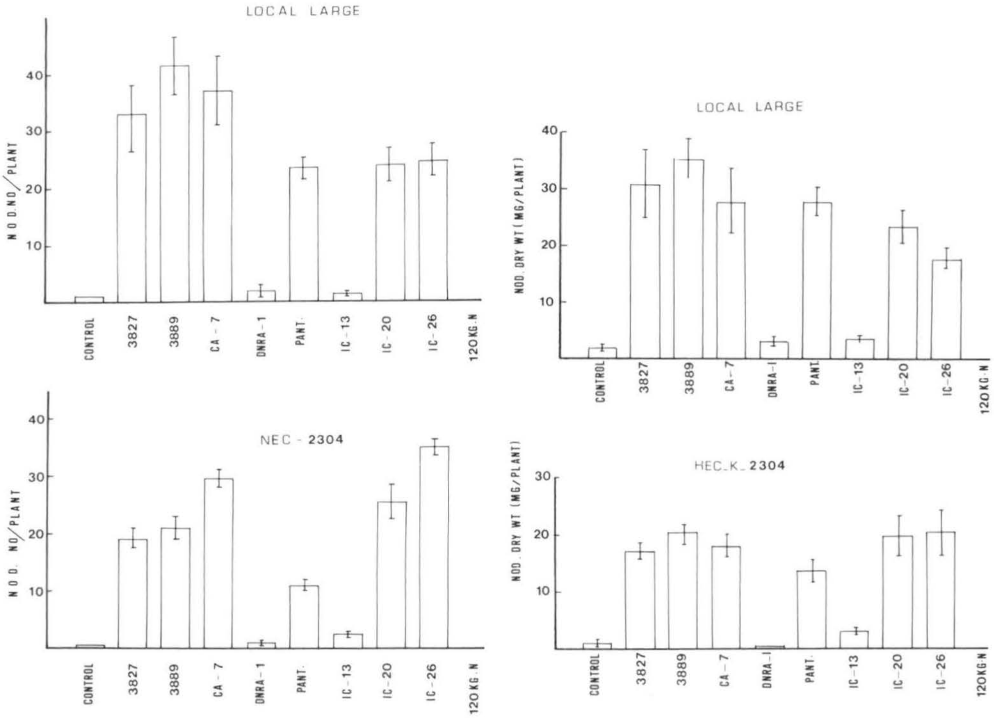

Fig. 2. Nodule production of two chick-pea cultivars when inoculated with eight Rhizobium strains.
Fig. 3. Nodule tissue development of two chick-pea cultivars when inoculated with eight Rhizobium strains.

particular problem at the ICARDA site near Aleppo. These studies are mainly geared toward the identification of *Rhizobium* strains suitable to the local environment and the development of host-strain combinations aimed at maximizing grain yield. In addition, the program is also attempting to identify chick-pea lines that have a superior nodule-forming ability both under conditions of low soil *Rhizobium* population in the absence of inoculation, and when inoculated artificially. Results to date and through observations on nodule-forming ability in lentils have enabled us to draw up lists indicating the chick-pea and lentil lines with superior and inferior nodule-forming ability (Table 2).

During the nodule assays, many hollow nodules were observed, apparently as the result of insect damage. The percentage nodule damage was scored for different lines and it was possible to identify certain lines that were more resistant and others that were highly susceptible to attack (Table 3). As this damage could be a major factor limiting nitrogen fixation and plant growth, especially if it occurs at a critical growth stage, more detailed studies of this problem are planned for the future.

This work, together with surveys of nodulation in farmers' fields and isolation of local *Rhizobia*, is building up more and more information on the base of variation available to plant breeders in the region and the ways in which this important attribute of the legume crops can be used in the overall crop improvement strategy of food legume research at ICARDA.

TABLE 2. Nodule-forming ability in various lines of chick-peas and lentils.

Crop	Cultivar[a]	Source	Nodule no./plant
High-Nodulating Cultivars			
Chick-pea	NEC-K 201	USDA	18.5
	NEC 82	INIA, Spain	15.0
	P-134-1	ICRISAT, India	14.5
	NEC K 210	USDA	12.0
	NEC-K 221	USDA	9.7
	NEC-K 202	USDA	9.0
Lentil	Local Large	Syria	56.7
	74TA 138	Morocco	56.0
	Giza 9	Egypt	50.1
	NEL 833	Egypt	48.0
	74TA 190	Turkey	34.9
	NEL 827	Egypt	33.4
	Local Small	Syria	33.3
Low-Nodulating Cultivars			
Chick-pea	F-272	ICRISAT, India	0.3
	PG-72-8	ICRISAT, India	0.7
	NEC-K 85	INIA, Spain	1.0
	C-235	ICRISAT, India	1.3
	NEC-K 139	IPI, USSR	1.3
	NEC-K 170	USDA	1.7
Lentil	NEL 435	Mexico	15.9
	74TA 567	Mexico	17.7
	NEL 441	Mexico	20.1
	74TA 550	Syria	20.3
	NEL 924	Iran	22.6

[a]Chick-pea, 103 lines tested; lentil, 32 lines tested.

TABLE 3. Resistance to nodule damage in lentil cultivars.

Cultivar	Source	% nodule damage
Resistant		
NEL 466	Chile	25.9
NEL 827	Egypt	38.5
74TA 260	Australia	38.9
Local Large	Syria	40.8
Highly susceptible		
NEL 280	Greece	84.4
74TA 434	Mexico	80.1
74TA 587	USSR	66.9
74TA 577	Mexico	64.5
74TA 209	Costa Rica	64.4

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The ICRISAT Chick-pea Program with Special Reference to the Middle East

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Chick-pea (*Cicer arietinum*) seems to have originated in western Asia and to have spread throughout Asia and North Africa at an early date. On the basis of the most recent evidence, *Cicer reticulatum* appears to be the most likely wild progenitor of the crop. The chick-pea plant is efficient in moisture utilization, and it thus thrives in semi-arid areas. Among the grain legumes, it ranks third in total world production and second in the Middle East, although, as most countries consume their produce locally, it figures only nominally in world trade.

The Production Situation

Since 1950, as is illustrated below, although there has only been a nominal increase in the area of chick-peas grown throughout the world, production has increased by about 16%:

	Area (*millions of ha*)	Production (*millions of metric tonnes*)
1950–53	10.03	5.47
1961–63	11.83	7.24
1974–76	10.23	6.34

During this same period, the area and production in the Middle East and North Africa have increased approximately 200% and 78% respectively, now standing at 707 000 ha and 586 000 metric tonnes. However, statistics indicate that since 1971 production from this region has in fact been declining. The bulk of the world's chick-pea production is derived from the Indian subcontinent (Table 1), with the Middle East and North Africa second and third in importance respectively. When seen against the background of the average world

TABLE 1. Area ('000 ha), yield (kg/ha), and production ('000 metric tonnes) of important areas of chick-pea during 1976.

Important area	Area	Production	Yield	% of total production
Indian subcontinent	9727	6658	637	89.18
North Africa	383	214	807	2.87
Middle East	265	250	867	3.35
Europe (Mediterranean)	202	105	520	1.41
Central America	190[a]	190[a]	1000	2.54
South America	14	9	723	0.12
World	10784	7466	692	100.00

[a] FAO estimate.
Source: FAO Production Year Book, Vol. 30, 1976.

yield the comparatively high productivity of chick-pea production in the Middle East and North Africa is highlighted. This is to a large extent a reflection of the importance of the crop to the region and the consequent depth of interest in its cultivation by the farmers.

Some Facts about the Crop

Chick-peas are grown in 34 countries of the world and of these, 24, including the countries of the Middle East, grow the large-seeded, white-coloured, kabuli types exclusively. The remaining 10 countries primarily produce the smaller seeded, multicoloured desi types, although these occupy more than 90% of the total area under chick-pea cultivation. In western Asia, northern Africa, and southern Europe, chick-peas are produced as a summer crop, in contrast to the Indian subcontinent, Ethiopia, Mexico, and certain other countries where they are grown over the winter months. Only a small proportion of the chick-pea area is irrigated; most of the crop is produced on conserved soil moisture with minimum inputs. Until recently, there has been a marked absence of chick-pea breeding efforts in the world and breeders in the past have worked on a relatively narrow genetic base, achieving consequently limited success. Systematic work on breeding for disease resistance has also been very limited, and other problems such as frost and winter hardiness, iron chlorisis, and heat, drought, and salt tolerance have remained largely unaddressed.

International Research on Chick-peas

ICRISAT, established in 1972 as part of a global effort to increase agricultural stability and productivity coordinated by the Consultative Group on International Agricultural Research (CGIAR), was assigned the international responsibility for the improvement of chick-peas. It has thus become the world coordinator for chick-pea research with a team of agronomists, plant breeders, germ-plasm botanists, pathologists, entomologists, physiologists, microbiologists, and biochemists contributing to the active improvement of the crop. More recently, with the establishment of ICARDA in 1976 to take responsibility for the improvement of chick-peas (amongst other crops) in the Middle East and North Africa, the capacity for research has been expanded. In view of the common objectives of both centres, a close working relationship has evolved between them to make the best use of the available resources and to avoid undue duplication of efforts, while at the same time strengthening the capabilities of the national research programs throughout the region to undertake their own improvement work. Situated at Hyderabad in India, ICRISAT is well placed to gear its primary efforts toward the desi cultivars, which are almost exclusively grown in the subcontinent, whereas ICARDA's work is emphasizing research into the kabuli types predominantly produced in the Middle East and North Africa.

Research at ICRISAT

The initial emphasis in chick-pea breeding at ICRISAT has been geared toward increasing the genetic potential of the crop for yield. Systematic breeding for the development of *Fusarium* wilt-resistant varieties has now been initiated and selection for other characters will be included in the program as rapid screening techniques are developed.

Breeding efforts are geared toward the generation of material and the development of technologies for rainfed and low-input chick-pea cultivation, and for this reason nurseries are grown, as far as is possible, without irrigation and with a minimum of fertilizer and pesticide input.

To make use of a wide genetic base, the breeding program involves large-scale hybridization. Early crosses of desi × desi types have produced some very good segregants and testing at 13 locations throughout India after bulking in the F_5 generation has revealed five lines yielding significantly better than the local checks at all locations. Such results indicate that the performance of desi types can be considerably improved by crossing within the group. At the same time, intercrosses between desi and kabuli types are considered to be important to introgress "yield genes" from one type to the other. To date, evidence suggests a limited scope for improving desi types by introgressions of kabuli genes, but introgressing desi genes into kabuli types may have some advantage. This is illustrated by the fact that 20 of the 29 kabuli varieties included in recent international nurseries resulted from intercrosses with desi cultivars. Studies of the performance of backcrosses of these intercrosses to both parents at two sites in India, and in Lebanon, have indicated that material generated at the Hissar site in the north of India may prove very useful for the conditions of the Middle East. Although this finding still requires confirmation, seed of selections made at Hissar is now being furnished to the countries of the Middle East for further testing.

Morphological Studies

Chick-peas are a relatively short crop and it is quite possible that the yield could be significantly increased by increasing plant height. However, the tall, compact, and erect types are at present very prone to lodging, are late in maturity, and bear few pods. A program initiated in the 1973–74 season in an attempt to remove these weaknesses has indicated that it is now feasible to develop tall cultivars with high yields and a normal maturity. Work in this field has, as a result, been intensified.

Disease Resistance

Chick-pea suffers from a large number of fungal diseases, of which the most important are wilt (caused by *Fusarium oxysporum* f. sp. *Ciceri*), root rot (*Rhizoctonia bataticola*), and blight (*Ascochyta rabiei*).

Laboratory and field techniques for screening for wilt have been developed at ICRISAT and a wilt screening nursery and a combined wilt/root rot screening nursery have been established. A large number of segregating populations from crosses with resistant sources were screened in the field for wilt resistance in 1977–78. Resistant material was identified in all generations (F_2 to F_7) and will shortly be made available to cooperators.

Ascochyta blight does not occur in the Hyderabad environment and all screening is thus carried out in an Isolation Plant Propagator in the laboratory. To date more than 3000 lines have been screened, but no source with a high degree of resistance has yet been identified, although a number of lines have given a rating of 3 on a 1–9 scale. In the future, field-screening at the ICARDA site at Aleppo, where the incidence of blight is high in early planted nurseries, should give more positive results. A number of wild species of *Cicer* have also been screened for blight resistance and one accession in the collection of *Cicer reticulatum* has been found to be apparently immune. Work is currently under way in an attempt to transfer this resistance into two desi cultivars.

There are indications of biotypes in both *Fusarium* and *Ascochyta* species and this could present problems in achieving stable resistance to these diseases. Investigations into this complication are also in progress.

Stress Tolerance

Physiologists at ICRISAT are at present investigating techniques for future improvement work designed to minimize the effects of stressful conditions on crop yield.

Preliminary drought-screening tests under limited moisture conditions indicate that selection for yield under stress is not very effective when moisture supply is adequate, and that early maturing cultivars tend to perform relatively well under moisture stress. Drought tolerance per se does not appear to be sufficiently closely related to yield to enable this character to be used as an indicator of yielding ability.

Experiments in progress indicate that the overall level of salinity tolerance in chick-peas is low, as compared to wheat or barley, and lower than other legumes, such as pigeon pea. However, there are indications that, at moderate levels of salinity, cultivaral differences in tolerance may exist and thus may be exploited in breeding efforts.

Cultivaral differences have also been noted in susceptibility to iron chlorosis, which may cause significant yield reductions in some varieties. Sprays of $FeSO_4$ have been shown to be useful in reducing losses in the more susceptible varieties.

Insect Resistance

Studies of insect damage at ICRISAT have confirmed that *Heliothis armigera*, the chick-pea podworm, is the most important insect pest of chick-peas, and that the losses caused by this pest are substantially higher in the kabuli cultivars than in the desi types. Limited observations made over the past 2 years have indicated differences in host susceptibility to this pest, and further investigations are currently under way in an attempt to discover sources of resistance and to develop screening techniques.

Protein Content

Over the past 2 years several hundred entries resulting from crosses made at ICRISAT have been analyzed for protein content. These studies indicate a range of 13.7–28.6% protein from the lowest to the highest and no differences between desi and kabuli types. Seed size does not appear to affect protein content in chick-peas. An experiment to investigate the effect of environment on protein content has shown that this factor may have a significant effect, and further investigation continues in this field. Studies designed to ascertain the mode of inheritance and to develop rapid screening tests for protein content are also in progress.

International Cooperation

Since 1975–76, ICRISAT has been coordinating international chick-pea nurseries and trials with the objectives of: making available elite germ plasm developed by the chick-pea breeders of the world to all cooperating breeders for testing; identifying genotypes suitable for use in the national breeding efforts; and supplying segregating populations of material to supplement the stocks of national and regional programs. All the cooperators are free to use any of the material provided, or even to release a cultivar in their own country, but they are asked to acknowledge the source. During 1977–78 the third international chick-pea nursery in the ICRISAT program was sent out to over 60 locations in 28 countries (Table 2.)

The results of the first and second nurseries are at present being compiled and will soon be available to cooperators. It has already become obvious though that many countries have found material from these two nurseries very useful in their own research efforts. For example, five of the highest yielding F6 bulks have shown substantial improvements over local varieties in multilocation testing throughout India, conducted in the All India Coordinated Trials.

Training facilities at degree and nondegree levels are available at ICRISAT and it is hoped to expand this program in the near future.

ICRISAT's Contribution to the Middle East

Within the overall spheres of research being conducted on chick-peas at ICRISAT, there are a number of ways that the centre can supplement and support the work of chick-pea improvement in the countries of the Middle East. These include: furnishing seed for nurseries and trials of desi varieties; actively exchanging kabuli breeding material between the Syrian and Indian centres; providing laboratory and field screening facilities for *Fusarium* wilt and root rot diseases, and laboratory screening facilities for *Ascochyta* blight; supplying seed of elite material especially developed for protein and other quality characters, such as insect resistance, nitrogen fixation, etc.; making available the world inclusive germ-plasm collection for use in ICARDA's program; providing training opportunities for personnel from the region; and assisting in the transfer and adaptation of new technologies developed throughout the region.

TABLE 2. International nurseries and trials sent out in 1977–78.[a]

Location		Material								
		ICCT.			ICSN			F_3 bulk		
Country	No.	DE	DL	K	DE	DL	K	D×D	D×K	MPT
Winter Planting										
India	29	5	10	5	13	17	5	11	3	1
Pakistan	4	–	4	4	–	4	–	2	2	–
Nepal	1	–	1	1	–	1	–	1	1	–
Bangladesh	2	–	2	1	–	2	–	–	–	–
Burma	1	1	1	1	1	–	–	1	1	–
Thailand	2	–	–	–	–	–	–	–	–	2
Philippines	1	–	–	–	–	–	–	–	–	1
Ethiopia	1	2	–	2	1	–	–	1	1	–
Sudan	1	–	–	1	–	–	1	1	–	–
Yemen Arab Rp.	1	1	–	1	–	–	–	–	–	–
Mexico	1	–	2	1	–	1	1	1	1	–
Chile	2	–	–	2	–	–	1	–	1	–
Peru	1	–	–	1	–	–	–	–	–	–
Argentina	1	–	–	1	–	–	1	–	–	–
Venezuela	1	–	–	–	–	–	–	–	–	1
Australia	1	–	–	–	–	1	1	1	1	–
Summer Planting										
Afghanistan	1	–	1	1	–	–	–	–	–	–
Iraq	1	–	1	1	–	–	–	–	–	–
Iran	1	1	1	1	–	–	1	–	1	–
Jordan	1	–	–	1	–	–	1	–	–	–
Syria	1	–	–	1	–	–	1	–	1	–
Lebanon	1	–	–	1	–	–	–	–	–	–
Turkey	2	–	–	2	–	–	2	–	2	–
Spain	1	–	–	1	–	–	1	–	1	–
Tunisia	1	–	–	1	–	–	–	–	–	–
Morocco	1	–	–	1	–	–	1	–	–	–
Libya	1	–	–	1	–	–	–	–	–	–
Tanzania	1	1	–	–	–	–	1	–	–	–
Total (28)	62	11	23	33	15	6	18	19	16	5

[a] ICCT, International Chick-pea Cooperative Trial; ICSN, International Chick-pea Screening Nursery; MPT, Micro-plot testing; DE, desi-early; DL, desi-late; K, kabuli; A, B, and C are equivalent to DE, DL, and K, respectively.

With both ICRISAT and ICARDA scientists working hand in hand with each other and with the other scientists of the region in the common goal of improving the productivity and stability of the chick-pea crop throughout the world, this important objective is brought closer with every day that passes.

Methods of Population Improvement in Broad Bean Breeding in Egypt

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The commercial varieties of broad bean currently used in Egypt are the latest in a series of varieties evolved through individual plant selection or hybridization in the cultivated Egyptian landraces, which are mainly of the medium- and small-seeded types. These varieties have a rather extended flowering period and are tolerant to chocolate spot (*Botrytis fabae*) and rust (*Uromyces fabae*), the most common fungal diseases of the country, especially severe in the North Delta of the Nile. As a result, the large-scale distribution and adoption of these improved types has led to a considerable improvement in both the level and stability of seed yield.

Selection from this rather narrow genetic base has, however, tended to result in varieties with very similar branching, flowering, and fruiting characteristics, and it seems that most of the original genotypic variation available from natural sources within the country has been exploited. As a consequence, little further progress is expected from the traditional improvement scheme involving selection from local land varieties. Despite this, studies of selected strains collected from different parts of the country have revealed differences in agronomic characters that could be used for further improvement and so this method still continues to be a part of the overall Egyptian breeding program.

In addition to the selection program, improvement efforts have also focused extensively on biparental crosses involving selections of landraces or landraces and introductions and aimed at improving disease resistance and adaptability. However, to date, only 1 cross out of 66, NA 29 (Holland) × Giza 1 (Commercial variety) has proved highly successful. This cross has resulted in the production of two varieties, namely Giza 3 and Giza 4, through the pedigree method. Giza 3 is tolerant to fungal diseases and has an average seed yield 11% greater than its parent Giza 1; it is well adapted to production in the North Nile Delta region. In contrast, Giza 4 is much more widely adaptable, yielding 5% more than Giza 3 in the South Delta and Middle Egypt regions and 6% more than the local variety Revaia 40 in Upper Egypt.

Population Improvement

In spite of the advances achieved by past breeding efforts it appears that line breeding based on recombinations from biparental crosses does not permit rapid progress in broad bean improvement. New approaches are thus needed to achieve the improvements in yield level and stability that seem possible.

Broad bean stands midway between a completely self-fertilized and a completely cross-fertilized crop, having on average one-third outcrossing and two-thirds selfing. In Egypt, considerable variation was found in the percentage of cross pollination, and this could be attributed to the varying climatic conditions affecting the prevalence of insect pollinators. However, unlike most self-fertile crops, broad beans require the action of an insect alighting on the flower to cause the dehiscing anthers to come in contact with the stigma (a process known as tripping). So, despite being only 33% cross pollinated, broad beans may be considerably reliant upon insects, specifically wild bees, to give adequate fertilization and hence good pod set. This is one of the reasons why seed yields tend to vary greatly between years and locations, depending to a large extent on the wild bee population.

In England, studies on the possibility of producing a completely autofertile broad bean crop have revealed the presence of many of the necessary characters in available lines but, in general, in association with low levels of seed yield and adaptation. The total number of pods per plant has been found to be a good selection index for improving seed yield in broad beans; however, a negative correlation between seed weight and pods/plant tends to limit the improvements that are possible by using this criterion.

It thus appears that there is considerable scope for improvement of this crop by methods aimed at breaking the association between low yield and high autofertility levels on the one hand and low number of pods per plant and high seed weight on the other. Even in the absence of linkages between characters, frequent hybridization is necessary to release variability, which is the prerequisite for selection. Therefore, a population improvement program that involves continual crossing designed to give the maximum opportunity for the rearrangement of genes in linkage groups and designed to provide a wide range of genetic backgrounds against which the genes and gene arrangements can be expressed seems to be the best method of tackling this problem. In addition, continuous selection will be essential so that the improvements generated by each series of crosses are accumulated and concentrated in the population. A system of recurrent selection, under which pressure is applied to a freely intercrossing population and the selected material is again intercrossed and subjected to selection, so that a series of crossing and selection cycles result in continuous genetic improvement, appears to be the breeding method best suited to satisfying both these criteria. This method, by which the population itself is improved from generation to generation, steadily increases the chance of identifying individuals with the required combinations of characters. These individuals are then propogaged as pure lines and form the new variety for multiplication.

Establishing Populations

Recognizing the potential of this breeding method, the broad bean improvement program in Egypt has been focusing on recurrent selection since 1974. Nine composite populations aimed at achieving varieties with higher adaptability, disease resistance, and good protein quality have been established in the intervening 4 years. Entries included in these composites are characterized by genetic diversity and desirable agronomic characters. They include cultivated landraces, hybrid derivative lines selected from yield trials, commercial varieties, and introductions. Each entry is represented by 5–10 seeds in each composite, which is grown in a 1 or 2 Saran screen compartment (mesh=20×20 mm) of 7.20 m $\times$3.60 m $\times$ 1.80 m in size.

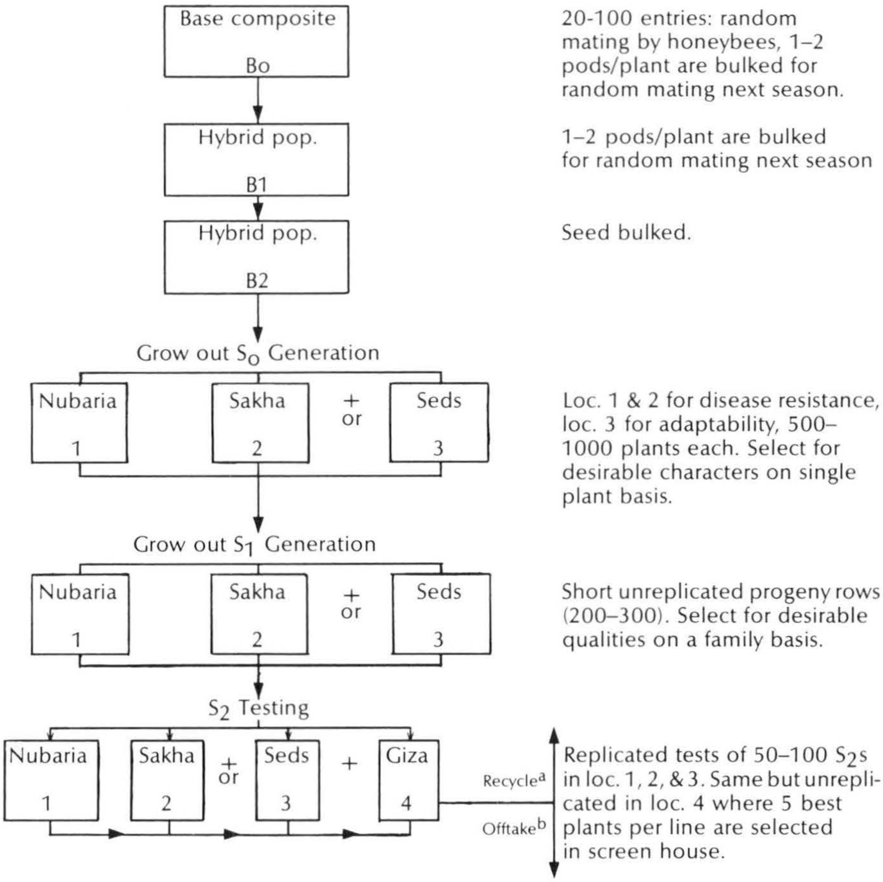
Increasing Random Mating by using Honeybees

To increase both cross-pollination and seed set, a small framed nucleolus beehive (60 $\times$ 45 cm) is placed in each Saran compartment immediately following flower initiation. The hive is supplemented with a new brood of honeybees every 10–15 days during the flowering season, which usually extends for up to 60 days. Studies using a genetic marker have indicated that, under these conditions, cross pollination can be as high as 79.9%. It thus appears that this technique is very useful as a breeding method to ensure a freely intercrossing population.

Recurrent Selection

Random mating, using the honeybees, is continued in the composite for three seasons, the composite in the second and third seasons being composed of the seed bulk from one or two pods sampled from each plant grown in the previous season. The remnant seed bulk can be handled as a hybrid bulk population on which the pedigree or improved bulk breeding method is applied to identify lines with the desirable characteristics.

After three seasons of recombination, the populations are then grown out for selection. Composites destined for selection with regard to disease resistance are grown at the Nubaria and Sakha research stations, and while those to be selected for adaptability, protein content, and other characters are grown at Seds. Replicated tests for yield determination are carried out in the S_2 generation at these three locations in addition to Giza, where the best selected lines from all the locations are grown for selection and recycling (Fig. 1).



[a]*Only the five selections in each of the 10% best performing lines over locations are recycled.*

[b]*Offtake for pedigree, selection, or bulk population improvement can be done at all stages.*

Fig. 1. Recombination and selection procedure for population improvement in broad beans (Vicia faba L).

With this program it is hoped that selection from continuously improving populations will result in the continuous generation of improved high-yielding disease-resistant and adaptable varieties suitable for production in Egypt.

Pollinating Insects: A Review

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Plant species of economic importance are either self-fertile and can set seed with their own pollen, or self-infertile, requiring pollen from other plants of the same species in order to set seed. Some self-fertile plants are automatically pollinated with pollen from their own flowers (self-pollinating) but often the flowers are so constructed that the pollen must be transferred from the anthers to the stigmas either by wind or through insects. The tasks required of an insect pollinator will thus depend upon whether the plant species is self-fertile but not self-pollinating, or self-infertile, and the efficiency per insect visit will vary accordingly.

Pollination of *Vicia faba*

Broad beans illustrate the effects of pollinating insects well as they are both self- and cross-fertilized. Insects contribute to seed set in two ways: upon entering the flower they cause the anthers to come into contact with the stigma (a progress called tripping), which results in self-pollination, and which may not otherwise occur; and they can cause cross-pollination by transferring pollen collected from other flowers recently visited. The degree of cross-pollination varies considerably between years and locations, depending largely upon the population of pollinators; it can be as high as 80% or as low as 5% under field conditions. With this degree of variation autofertility is obviously an important characteristic in broad beans, as it enables good yields to be produced even in the absence of pollinating insects, and thereby reduces seasonal yield variations.

Pollinating Insects

Broad bean flowers are quite large and conspicuous and, having nectaries both at the base of the corolla tube and on the underside of the stipule, are fairly attractive to insects.

The essential pollinators of legumes in general and broad beans in particular are bumblebees of the genus *Bombus* and honeybees of the genus *Apis*. These insects have sufficient body hairs for effective pollen transfer; the necessary behaviour patterns at the flower; and forage continuously, visiting a large number of flowers every day. Apart from these essential pollinators, other insects, especially *Dipterans* from the genera *Eristalis*, *Syrphus*, *Platycheirus*, *Rhingia*, *Calliphora*, *Lucilia*, *Sarcophaga*, *Bibio*, *Dilophus*, and *Bombylius*, are considered to be useful secondary pollinators.

Within the genus *Bombus*, some species of bumblebee (e.g., *B. lucorum* and *B. terrestris*) may collect the nectar by biting holes into nectaries at the corolla base. They thus do not enter the flower and are not effective at either self- or cross-pollination. However, other species, such as *B. agrorum* and *B. hortorum* have proved to be excellent pollinators.

The pollinating potential of a single honeybee colony becomes evident when it is realized that its bees make up to 4 million foraging trips per year and that during each trip an average of about 100 flowers are visited. Estimates of the number of colonies needed to effectively pollinate a given area of crop vary considerably and are usually based on the experience and assumptions of individual growers. The rate of 2.5 colonies per hectare has been quoted extensively; however, the population required will obviously vary considerably with the concentration of flowers, their attractiveness and the percentage that are open at any given stage of flowering, competing insects, crop species, and location, so it would be misleading to quote flat rate figures.

Bees are attracted to flowers and recognize them by their colour, shape, and smell. They are able to distinguish four qualities of colours (yellow, blue-green, blue, and ultraviolet) and when they are working flowers of a single colour, tend to become conditioned to that colour and fail to visit different coloured flowers. However, when a species has flowers of more than one colour, bees readily change between them and thus may be seen to ignore colour as a distinguishing character. Bees are also able to learn the general shape of flowers and the general form of plants, but their visual perception is slight and they readily move between tall and stunted plants and flowers at different stages of opening. Although the general form of the plant and the colour of its flower seems to guide bees from a distance, these insects have a highly developed sense of smell, and scent apparently provides the stimulus to alight on the flower when a bee is close to it. It has been shown that the addition of a strange scent to flowers will discourage foragers from visiting.

Pollination Control

From a breeder's point of view, pollination control implies two aspects: the need to increase cross-pollination as a breeding technique on the one hand; and the need to reduce cross-pollination to ensure purity of lines on the other.

Studies are under way to determine the best way of distributing colonies among crops so that foraging and the proportion of flower visits is increased. Various cultural methods, including fertilizer use, the presence or absence of irrigation, plant spacing, and the use of wind breaks, have been investigated in an attempt to improve the attractiveness of crops. Whenever practicable, the arrangement of competing crops so that they flower at different times and restriction of the acreage of any one crop reduces the dilution of the pollinators and results in improved pollination.

There appears to be a relation between the intensity of a pollen's odour, its attractiveness to bees, and hence its selection. It has been reported that pollen contains phytosteroles that attract bees and has been further demonstrated that the removal of materials contained in a hexane or ethyl extract of pollen results in a rejection of the residue by bees, despite its containing over 97% of the dry weight and the bulk of the nutritive substances. Further studies have isolated and identified a C18 straight chain trienoic acid that was highly attractive to honeybees and that, when added to a dish of cellulose powder, precipitated 15 times as many visits from foraging bees as similar control dishes. The artificial synthesization of such attractants and their use in target crops may prove an effective way of increasing visits by bees and consequently pollination.

The control of pollinators to reduce cross-pollination is an altogether more difficult task. At present the only fully effective method of excluding bees from the crop is to isolate it within a cage. However, little work has been carried out on this problem and the use of varieties bred for flowers with long corolla tubes, attractive crops planted around the desired bee-free area, and insect repellants are subjects deserving attantion in future work in this field.

Section VI
Cooperative Approaches to Food Legume Improvement at the National Level

The Training and Communications Program at ICARDA

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The training and communications effort at ICARDA is designed to assist in the process of exchange of information, knowledge, skills, and technology related to the development and improvement of food legumes. To this end, staff from the Training and Communications Program and the legume scientists at ICARDA have been working closely together in the development of a series of training courses, conferences, workshops and seminars, educational materials and audiovisual aids, and public information materials featuring current efforts and results of field research. While providing the necessary support for ICARDA's research efforts, this program also addresses itself to the needs of the national research institutions for technical information and trained manpower. More specifically the objectives of the food legumes training and communications efforts are:

- to provide research workers from the region with training opportunities leading to a better understanding of new skills and a comprehensive knowledge of food legume field research methods;
- to make available to researchers the necessary scientific information concerning effective research technology and findings related to food legume improvement in the Middle East and North Africa Region;
- to bring together researchers from various countries to discuss problems and exchange ideas and strategies concerning the improvement of food legume research and production;
- to assess the structure, nature, and limitations of current food legume research and production efforts within the region;
- to develop, with the national research programs, methods and strategies for the identification of research problems related to food legumes at the local level in each country;
- to establish a common understanding of the major problems of research and development of food legumes and their place within the farming systems of the region.

To accomplish these objectives, the Training and Communications Program focuses its efforts on four main thrusts:

(1) The conducting of training courses at various levels of technical skill for research personnel in the region;

(2) the production of publications, newsletters, and other illustrative materials required for publicity, technical information dissemination, or educational purposes;

(3) the organization of workshops, conferences, seminars, and field days relevant to the issues and problems concerned with the research and development work carried out at ICARDA;

(4) the coordination and support of cooperative research both between ICARDA and the research efforts of the region and between the national programs themselves.

These areas are seen as the fundamental functions existing within the overall sphere of communication itself. They are considered as being intimately connected so that efforts in any one sector provide benefits to the sphere as a whole.

The Training Program

Priorities and Guidelines

This program is aimed and geared toward several different levels of education and is seen as serving the dual functions of increasing and improving cooperative work and generating publicity, as well as its more basic role of increasing the technical expertise of the participants. The program is structured to provide three main types of training.

In-Service Training

At the present time the main emphasis of ICARDA's training efforts has been placed on the middle level research personnel from the national research programs of the region. The bulk of these people have not enjoyed in-depth academic training; some of them are not university graduates and many of those who are have little experience in the theory and practice of field research. Through residential courses, varying from 2 weeks to 8 months in length, it is aimed to provide such participants with the training necessary to effectively bridge the gap between the high level theorists and the low level technicians at present existing in many of the research efforts of the region.

Observations have indicated that research as a job must be learned by experience. In recognition of this, ICARDA's in-service courses emphasize field training and the acquisition of practical skills related to research work. These skills are taught alongside a background of theoretical scientific training, which aims to give the participants sufficient confidence to effectively undertake practical work and at the same time provide them with the scientific knowledge essential to the structuring and implementation of effective research work.

Degree-Related Research Training

Through the provision of opportunities to conduct relevant thesis research under the guidance and supervision of ICARDA scientists, this program aims to give graduates at the M.Sc. and Ph.D. levels the field experience and specialized training necessary for their future work with the research efforts of their own countries.

Training with Universities

Students from agricultural faculties of universities in the region are encouraged to work on ICARDA field experiments to gain practical research skills under the supervision of the scientific staff of ICARDA. At present, this activity is limited but it is hoped that as facilities expand, the program will be able to cater for an increasing number of participants from neighbouring countries.

Organization

The Training and Communications Program has administrative, organizational, and educational responsibility for these activities. The courses themselves are run under the supervision of senior research personnel from the Food Legume Program, together with a training officer who is qualified in agronomy and charged with the development of educational materials and instructional techniques, as well as the overall course organization.

Current training activities are confined almost exclusively to the training of middle level personnel through in-service courses, which usually span the cropping season from February to July. The participants spend the bulk of their time in the field putting into practice the main concepts and skills necessary for a successful legume research program.

In addition, lectures, manuals, and other educationsl materials, focusing on both theoretical and practical research methods related to the development and improvement of lentils, chick-peas, and broad beans are provided as a supporting core of background information. The courses, apart from providing the participants with the necessary knowledge of legume research, also aim to give them a comprehensive overview of the position of food legumes in the economic, social, and farming systems of the region.

The Publications and Communications Service

Guidelines

The main function of this component of the overall Communications Program is the provision of information. The information services provided by the program fall into four major categories:

(1) the provision of information, in the form of technical reports and comprehensive descriptions of experiments and trials undertaken and results obtained at ICARDA or at any of the national research institutions, to collaborating scientists;

(2) the development and provision of educational materials and training packages, including manuals, visual aids, and other materials, based on the research work being carried out at ICARDA, both to trainees at ICARDA and to national programs wishing to initiate their own training components;

(3) the provision of general reports and other informative material to the public, specifically agricultural planners, donor agencies, and other interest audiences, to enable them to stay abreast of the latest developments and achievements at ICARDA and throughout the region as a whole;

(4) the assistance, where necessary, of the communications efforts of national programs in the region, involving the preparation and production of technical reports, information, and educational materials related to the improvement and production of food legumes.

Organization

To fulfill these functions, the following publications are being produced:

- An ICARDA Newsletter, published quarterly in English, French, Arabic, and possibly also Farsi, providing general information on developments at ICARDA for a very wide audience.
- A Food Legume Newsletter, published biannually and focusing on food legume research, development, and improvement at ICARDA, in the region, and at other international centres and research institutions. This publication is designed for distribution to collaborating national programs, government officials, and research workers in the region.
- An Experimental News Service (similar to that already developed in Canada for lentils) covering all aspects of broad bean research around the world and aimed at all scientists involved in the improvement of this crop.
- Annual Technical Reports on activities and accomplishments at ICARDA, and Special Reports on specific projects. These are directed toward policymakers, agricultural planners, and other concerned audiences.
- Comprehensive Scientific Reports, with detailed descriptions of the design, implementation, and results of experiments carried out at ICARDA, for dissemination to scientists in other international and national institutions concerned with food legume research.
- Popularized articles, publications, and monographs related to food legume production projects undertaken or supported by ICARDA. These articles will be written by local and international journalists and writers and geared for the layman and other audiences not involved with the technical aspects of agricultural research.
- Training manuals, technical publications, and booklets in support of ICARDA training courses and for use by research personnel at the national level. All this material will be published in English and translated through special contracts at the local level to ensure applicability and relevance to the local situations.

Conferences and Workshops

This component of the Training and Communications Program is involved with the organization, together with participating scientists, of conferences, workshops, seminars, and field days related to ICARDA's activities. It is closely integrated with the other communication functions so that in addition to its primary role, it also provides opportunities for trainees to gain experience through participation, stimulates the strengthening and promotion of increased cooperative activities at all levels, and generates material for publications to serve a variety of purposes.

Specifically these activities involve the organization of: workshops related to problems of food legume production and improvement within the region; seminars and symposia related to specific problem areas identified by ICARDA or the national legume research programs; and field days designed to demonstrate to national research workers the operations and achievements of food legume research at ICARDA.

Cooperative Support Service

Work in this field involves supporting ICARDA'a efforts in establishing cooperative programs and thereby strengthening its contribution to national research and production programs. Furthermore, this service will provide the necessary support to ICARDA scientists in the planning and implementation of cooperative projects aimed at the effective transfer of newly developed technologies to the national research efforts of the countries of the region. Activities primarily involve assisting in the organization of training and research workshops and conferences at the national and local level, together with the collection, interpretation, and dissemination of technical information concerning the countries of the region and information feedback to these countries about the results of ICARDA's research and training activities.

The four components of the food legume training and communications efforts at ICARDA, namely, training, information provision, conferences and workshops, and cooperative activities, are organized by communications and legume research personnel in very close association. These efforts are providing a channel through which the legume improvement work of ICARDA is becoming closely linked with the other relevant research efforts, both within the region and throughout the world. Such strong and developing linkages are helping to ensure that the work of ICARDA is finely tuned to the real problems of food legume production and improvement facing the farmers of the region, and that ICARDA and the national research efforts of the region work hand-in-hand toward the solution of these problems and thereby bring closer their common aim of increased and more stable food legume production.

FAO Food Legume Programs in the Middle East and North Africa

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Broadly defined, food legumes include the group of crop species of the family Leguminosae that are consumed by human beings either directly as mature dry seed, immature green seed or green pods, or indirectly as vegetable oil. Food legumes consumed as dry seed are often referred to as grain legumes or pulses.

Food legumes are of special social and economic significance because they provide an important fraction of vegetable protein, oil, and calories to the diets of the rural poor. In addition, these crops are of high value to agriculture as a result of their ability to maintain soil fertility through nitrogen fixation. They are widely cultivated by small holders for domestic consumption, and are frequently grown as subsistence crops on marginally productive land.

Yields of pulse crops in many developing countries are generally very low relative to other food staples, especially cereals, and to legumes produced in the more developed countries. The low yields and low overall productivity may be attributed to many major constraints, which include: the inadequate appreciation of the importance of the crops by policymakers and planners; the strong competition exerted by other main food and cash crops yielding a higher economic return, resulting in the replacement of pulses by more profitable crops or the stagnation of area and production, such as has occurred in the Middle East and North Africa (see Table 1); the lack of effective research programs and

TABLE 1. Area ('000 ha) and yield (kg/ha) of food legumes in the Middle East and North Africa.

	1961–65 (avg)		1976	
Country	Area	Yield	Area	Yield
Afghanistan	28	1585	35	1624
Algeria	66	526	98	768
Egypt	242	1697	168	2117
Iran	198	835	173	1040
Iraq	42	851	56	722
Jordan	48	630	23	359
Lebanon	11	1033	21	907
Libya	6	351	7	988
Morocco	403	603	567	853
Pakistan	1674	511	1477	531
Saudi Arabia	2	1593	3	1643
Sudan	47	1090	72	1073
Syria	194	775	231	738
Tunisia	84	395	133	626
Turkey	570	1038	613	1235
Yemen Arab Republic	37	1021	75	1221
Total	3652		3752	

Source: FAO Production Yearbook, Vol. 30, 1976.

experienced personnel, and the consequently minimal amount of varietal improvement, introduction, evaluation, and germ-plasm conservation work under way in many of the countries of the region; the embryonic state of development of many of the seed mutliplication and distribution efforts; and the deficiency of production technologies designed to maximize resource use and pathways through which such information can be channeled to the farming community.

In recognition of the importance of food legume crops to agricultural development in many of the less developed countries, the post of "Agricultural Officer — Food Legumes" was created at FAO headquarters in Rome. The incumbent of this post is directly responsible for matters involving the improvement and implementation of programs related to improving productivity.

Further involvement in the field of grain legume improvement arises from FAO's position as one of the three cosponsors of the Consultative Group on International Agricultural Research (CGIAR). The CGIAR has in turn sponsored the establishment of nine International Agricultural Research Centres (IARCs), five of which are actively involved with research and development programs on a wide range of legume crops, which include broad bean, dry bean, chick-pea, cowpea, groundnut, lentil, mung bean, pigeon pea, winged bean, and soybean.

The Food Legume Production Program

FAO's global program designed to improve food legume production both quantitatively and qualitatively involves three main spheres of activity: general agronomy, research and training, and liaison and information.

General Agronomy

Within this area, FAO organizes intercountry cooperative variety trials aimed at identifying high-yielding varieties with improved agronomic characteristics and wide adaptability; supports the development of suitable agrotechniques, which include better crop management and improved pre- and postharvest technology; promotes the expansion of food legume production into new areas through the encouragement of intensive production methods, such as intercropping, multiple cropping, and the development of suitable farming strategies aimed at better utilization of land and water resources and an increased income per unit area; and attempts to determine the quantitative requirement for food legume seed and to identify potential national and intercountry level, medium- to long-term seed production programs that could be developed to meet this requirement, together with the necessary investment costs.

Research and Training

FAO is involved with the promotion of intensive plant breeding programs designed to identify high-yielding and high quality pulse varieties with improved nutritive value and plant ideotype. In addition, considerable support is given in the strengthening of national research efforts to improve these programs and increase their technical manpower, facilities, efficiency, and effectiveness. FAO cooperates in the collection, conservation, utilization, and exchange of plant material and genetic resources and is instrumental in organizing training courses, workshops, and seminars for wide audiences. Such courses involve breeders, agronomists, extension workers, farm managers, and farmers and are aimed at developing increased national competence in the solution of problems at the farm level.

Liaison and Information

The development of suitable regional cooperation in research and development of food legume crops is considered to be of great importance, and FAO is actively involved in establishing linkages between relevant regional and international centres, institutes, and programs to facilitate the free exchange of materials and information. FAO also acts as a collector, processor, and disseminator of information related to the most efficient and effective technologies for food legume production and improvement.

Current Program Activities

Within the overall global framework outlined, FAO's current food legume program in the Middle East and North Africa involves a large number of interrelated projects covering all FAO's spheres of activity.

General Projects

Since 1951, under the auspices of the United Nations Development Program (UNDP), FAO has been assisting the countries of the region through a variety of projects of varying size, embracing grain legumes as an important component of the development of food crops in general. Furthermore, through its regular program, FAO staff, based at Headquarters in Rome and at the Regional Office in Cairo, provide technical advice and policy guidelines for the operation of improvement programs in specific countries.

A project concerned with a coordinated and cooperative program of improvement and production of cereals, food legumes, and oilseeds has been under way in the Near East and North Africa for several years. This project involves programs carried out in collaboration with the national research institutes of 22 of the countries of the region and is coordinated by a Regional Food Legume Officer located in Teheran. The work of the project includes: the organization and assistance of multidisciplinary national research task forces; the conducting of, and preparation and distribution of the results of cooperative yield trials involving promising varieties of food crops; and the identification of national needs for additional manpower.

Field performance trials on five food legumes, namely chick-pea, dry bean, broad bean, cowpea, and lentil have been operated in seven countries of the Middle East since 1974.

A large-scale project is currently being considered, in cooperation with the Swedish International Development Agency (SIDA), for implementation in Bangladesh, Egypt, Ethiopia, India, Iran, Pakistan, and Turkey. This project aims to link relevant research in developed countries with that in developing countries, promote intercountry cooperation through training, and aid in the more widespread dissemination of information and material between countries.

Genetic Resources Activities

The International Board for Plant Genetic Resources (IBPGR), the secretariat of which is located at FAO headquarters, is supporting national genetic resources programs in several countries of the region, and encouraging, as far as is possible, regional and interregional cooperation in these activities. Under a new IBPGR project, two plant genetic resources scientists have been stationed in Iran, where they are assisting with the development of the Iranian program, as do comparable units in Syria and Afghanistan. Collection missions involving food legume species have been undertaken in cooperating countries and additional missions are planned for the near future.

Specific Research Projects

A project involving disease and pest resistance in grain legumes is currently being conducted in Morocco under the International Program on Horizontal Resistance (IPHR), initiated by FAO in 1975. The main problems being addressed are blight and leaf miner attacks in chick-peas, and infestations of the parasitic broomrape (*Orobanche*) in broad beans. Methodologies for effective transfer of resistance through breeding are at present being developed for both crops and these will be used in this, and hopefully other similar projects, to build a high degree of horizontal disease and pest resistance into these crops.

In 1977, FAO established an Action Program for the Prevention of Food Losses in Cereals, Grain Legumes, Roots and Tubers. This project is specifically designed to assist developing countries in their efforts to identify food losses that occur throughout the postharvest system, and to plan and implement national programs to reduce these losses.

Seed Production and Distribution Activities

The development of sound national seed multiplication and distribution programs for the production of quality seed of newly developed high-yielding varieties is considered of vital importance by FAO. To this end, the FAO Seed Improvement and Development Program (SIDP), which started activities in 1973, is now providing assistance to 73 countries (including all of the Middle Eastern and North African nations). SIDP acts as a forum for the channeling and coordination of assistance offered by governmental, nongovernmental, and international institutions in the development of seed production, quality control, and distribution activities. It assists in the identification, formulation, and implementation of national seed programs and field projects at all stages, with the overall objective of enabling countries to become self-sufficient in seed production.

At its headquarters in Rome, the FAO Seed Exchange Laboratory handles between 60 000 and 100 000 seed samples annually and is continuously supplying countries of the region with seed for experimental work. Food legume seeds distributed include broad bean, chick-pea, dry bean, lentil, mung bean, pea, groundnut, cowpea, and soybean. Material for distribution under this program is obtained from various sources: soybean from INTSOY (the International Soybean Program) based in Illinois, USA, and the International Institute for Tropical Agriculture (IITA) in Nigeria; chick-pea from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India; cowpea again from IITA; and mungbean from the Asian Research Centres.

With financial support from the government of Bahrein, FAO also operates a regional project for the supply of seeds in bulk (up to several tonnes) to the countries of the region. To date, this has involved supplying improved seed of soybean and groundnut varieties to Egypt, Pakistan, Syria, and the People's Democratic Republic of Yemen for extensive testing and early multiplication.

Training and Conference Projects

In collaboration with the Danish International Development Agency (DANIDA), a 4-month training course concerned with the improvement and production of food legumes was organized in 1975. This course involved 16 participants from 10 countries of the region and its success has prompted a similar, but longer duration, course to be arranged for 1980, together with an appreciable increase in the training opportunities offered to legume research personnel in the region.

Also in operation is a project aimed at strengthening national institutions through the training of scientists in field food crops, sponsored by the Kingdom of Saudi Arabia. This project has two aspects, namely a 12-month group training program on systems of farming in rainfed areas conducted at Roseworthy Agricultural College in South Australia on an annual basis; and a training program on production of important field crops, which offers four fellowships on soybean production agronomy and two on groundnut production agronomy at universities specializing in these fields.

The Second FAO/SIDA Seminar on Field Crops in Africa and the Near East, attended by 146 participants was held in 1977. An important section of this seminar was devoted to the problems of food legume production and the strategies for the improvement of these crops.

Information Services

The collection and dessimination of information concerning new developments in crop improvement and production methodology is a very important part of FAO's central assistance role. This is achieved through the preparation of technical publications (three recent technical papers have been devoted to food legumes), and the documentation and indexing of current materials.

FAO provides the coordination for all the activities of the International Information System for the Agricultural Sciences and Technology (AGRIS). This is a decentralized system that collects information from participating countries and organizations, processes it, and then provides selected information to field workers, research organizations, educational institutions, and other interested parties through a worldwide current awareness service and a network of information and documentation centres divided into subject matter or geographical location.

Another mechanism for information dissemination located at the FAO headquarters is CARIS (the Current Agricultural Research Information Service). CARIS is a cooperative system that provides developing countries with information on current research at various institutions and in various programs throughout the world. Its basic aim is to improve communication between research efforts to evaluate their adequacy and thus identify major gaps and weaknesses in the overall sphere of agricultural research, thereby assisting in decision-making at both the national and international levels. The CARIS project is, moreover, an attempt, the first of its kind in the world, to make as complete an inventory as possible of the sum total of agricultural research efforts in the developing countries.

Assistance Available

The projects and activities outlined are examples of the wide range of work at present being undertaken by FAO in the important field of supporting and promoting improvements in food legume production across the world as well as in the Middle East and North Africa region. FAO is committed to cooperate with and assist member governments and institutions concerned with food legume production and improvement, as much as its resources permit, along the following lines:

- FAO has a long and wide experience in project identification, preparation, appraisal, and implementation and in the methods of acquiring suitable financing. Assistance in any of these areas will be gladly given;
- FAO has a strong and expanding training program for the development of research and technical manpower at all levels and would welcome further participation in these activities;
- FAO has recently initiated a new technical cooperation program under which assistance up to the value of $250 000 is granted to any project of 1 year's duration requested by member governments, subject of course to it meeting certain criteria;
- The services offered by the FAO SIDP are always available for utilization;
- The FAO Seed Exchange Laboratory will supply seed samples and genetic material of food legume crops to scientists of the region on request;
- Provision for holding meetings, consultations, seminars, and workshops at FAO is always made if such gatherings are programmed and planned well in advance;
- Under FAO's regular program, short-term consultancies can be commissioned when advice is urgently required for any particular situation;
- FAO's information gathering, documentation, and dissemination system is unique in its scope and geographical coverage. This system is open to use by all interested scientists, researchers, and institutes in the region;
- FAO will maintain active and strong relations with national, regional, and international institutes and centres located in the Middle East and North Africa and concerned with aspects of food legume improvement and production, and will always be available to assist in any of these ventures.

The Food Legume Improvement and Development Program of the Field Crops Section at ACSAD

L. R. Morsi

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Wheat, barley, sorghum, lentil, chick-pea, and broad bean are the main food crops cultivated in the arid and semi-arid areas, and are considered to be of vital importance as sources of nutrition in the countries of the Arab world. To increase the production of these crops horizontally is difficult, if not impossible, in many of these countries due to the severely limited amount of land that can be used for rainfed agriculture. Any increases in production must thus arise primarily through vertical expansion (i.e., increasing the yield per unit area). This may be achieved through a combination of crop development through breeding, and adaptation of high-yielding varieties to the conditions of the region; development of cultural methods and practices designed to conserve soil moisture and ensure its most efficient utilization by the crops; and evolution of production machinery and methods specifically designed for dryland agriculture.

To this end, the Field Crops Section of the Arab Center for Studies of the Arid Zones and Dry Lands (ACSAD) has been established to combine the efforts of specialists from the Arab countries and the available physical resources of the region into a program aimed at developing crops that will produce high and stable yields under the prevailing low and variable rainfall conditions of this part of the world.

Most of the fieldwork at ACSAD is carried out at Izra'a, in southern Syria, which has a Mediterranean-type climate with an average annual rainfall of 300 mm. The soils of this area tend to be of the terra rosa type.

The Food Legumes Research Program

This program, which was initiated in 1977, focuses on the improvement of the three major food legumes of the region, namely, lentils, chick-peas and broad beans. Research will initially be directed toward the development of improved varieties and production practices specifically suited to the drought region of the Arab world, through an interdisciplinary approach involving breeding, physiology, agronomy, weed control, mechanization, microbiology, and seed quality. It is planned to commence a regional nursery program, distributing screening/observation nurseries, field trials, and segregating populations to cooperators in Arab countries in 1979.

Work on food legumes during the 1978 season involved the testing of segregating populations, observation lines, yield trials, and other specific nurseries received from a number of different sources in the region.

Segregating Populations

A collection of populations from various sources is at present being studied to identify germ plasm that may be of value for crop production under dryland conditions. Some crosses between promising lines are planned for the 1978–79 season.

Observation Lines

Since the 1975–76 season, observation lines have been maintained for the three main legume crops. These lines are a composite of a number of local selections together with material received from regional and international nurseries. Lines planted at Izra'a in the current season include:

	No. entries
The Lentil Regional Nursery (LRN-78)	91
The Chick-pea Regional Nursery (CRN-78)	91
The International Chick-pea Observation Nursery	100
The Broad bean Regional Nursery (BRN-78)	76
The Arabian Broad bean Observation Nursery	120
The Arabian Chick-pea Observation Nursery	150
The Arabian Lentil Observation Nursery	180

Variety Yield Trials

Six of these trials were planted during the 1977–78 season. These were:

	No. entries
The Lentil Regional Preliminary Yield Trial (LRPYT-78)	36
The Lentil Advanced Yield Trial (LAYT)	36
The Chick-pea Regional Preliminary Yield Trial (CRPYT-78)	36
The Broad bean Regional Preliminary Yield Trial (BRPYT-78) (large-seeded)	21
The Broad bean Regional Preliminary Yield Trial (BRPYT-78) (small-seeded)	25
The International Chick-pea Cooperative Trial	25

As the legume research work at ACSAD expands in the coming years, it is looking forward to increasing and fruitful cooperation with other research programs and international agencies. In this way all the related agricultural research in the region can work together toward the common goal of increasing agricultural productivity, especially in the more marginal areas of the region.

The Role of IDRC in Food Legume Improvement Research

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The importance of food legumes, particularly in the diets of the poorer and less well-nourished people of the world, is a well-established fact. In most of the developing countries, most of the poorest people, especially in the rural areas, derive perhaps 75% or more of their nutritional requirements, in terms of calories and protein, from plant sources. The cereal and pulse crops dominate in this respect and, in their protein supply, complement each other well in human nutrition.

In spite of their very significant role in human nutrition, their ability to survive and yield under extremely marginal conditions, their contribution to crop rotations, and their nitrogen-fixing capacity, little emphasis or importance has been attached to the improvement of food legume crops by the agricultural scientific community in the past, the cereal crops being the main focus of research and development efforts. It is thus hardly surprising that world cereal production is currently increasing at a much more rapid rate than the production of legumes. In fact available statistics indicate that during the past 20 years per capita legume production in Asia and Africa has been declining while cereal consumption has increased. The improvement of only one component of these two complementary staple food crops, at the expense of the other, to a certain extent suggests that the nutritional quality of the diets of the poorer sections of the population of this region may be deteriorating.

Recognizing this situation, the International Development Research Centre (IDRC) is working toward the correction of this imbalance through the encouragement and support of research designed to develop legumes capable of giving higher yields combined with improved nutritional quality, in the major producing regions of the semi-arid tropics and West Asia.

Since its inception in 1972, the Pulse Improvement Program of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), based in Hyderabad, India, has received active support from the Centre. Breeding and selection of lines of chick-pea and pigeon pea at ICRISAT is geared toward achieving higher and more stable yields together with higher protein content and resistance to diseases, pests, and other stressful conditions. Thousands of different lines of these two crops have been collected from all over the world and a very active improvement effort is now fully under way.

Other IDRC-supported food legume research projects are under way in the West Indies, Kenya, and Sri Lanka, and a network of cowpea improvement efforts is currently being initiated in West Africa, involving several countries, and the International Institute for Tropical Agriculture (IITA).

In West Asia, IDRC was instrumental, in cooperation with the Arid Lands Development Program of the Ford Foundation (ALAD), in the setting up of a regional food legume program. This was expanded with the formation of ICARDA into an internatinoal effort focusing upon lentil, broad bean, and chick-pea improvement. In coordination with ICARDA, a network of national pulse improvement programs involving Algeria, Sudan, Egypt, Syria, and Turkey is being built up at the present time. This development is in line with the IDRC philosophy manifest in all its programs that indigenous scientists should be encouraged and assisted to develop their own national research competence with the technical backup and assistance of the international research community embodied in the international research centres.

With this approach, IDRC attempts to bring together the legume research efforts of the developing world on the national, regional, and international levels into a coordinated and cooperative endeavour to improve the production of food legume crops and through them the nutrition of the world's population. The fast-developing relationship between ICARDA and the national pulse programs of West Asia and North Africa, and the new links in the chain of this cooperation that are continually being forged, provide a good example of the ways in which research efforts on all levels should work together toward their common aim. In this way research can make a real and lasting contribution to the alleviation of the hunger and hardship that exists in the world today.

Section VII
Recommendations for Future Priorities

During the workshop, much of the participants' time was spent in small problem-oriented discussion groups. These were designed to focus on specific areas of interest within the whole sphere of food legume production and improvement and to evolve concrete recommendations for future research priorities. The findings of these groups are set out in the section that follows.

Dietary Importance and Consumer Requirements

(1) The dietary importance of food legumes is considerable in light of the deficiency in animal protein sources in most of the countries of the region. More information is now required on quality demands, which vary between crops and groups of people (babies, growing children, adults, etc.).

(2) The processing industry is growing rapidly in some of the countries of the region and processing methods and factors affecting the quality of canned legumes need to be clarified to develop improved products.

(3) The term "cooking quality" is not well defined. Standardized methods must be developed for testing different quality components (e.g., flavour, cooking time, seed texture, palatability, etc.), so that results from different institutions may be compared.

(4) Little information is available on the incidence of "favism" in the different countries of the region. The extent of the disease and the factors responsible require more study. Proper testing and screening methods must be sought to eliminate these factors from improved varieties.

(5) Contradicting data are available on the patterns of legume use (dry seed vs green pods and seed), especially for broad beans. Present improvement efforts should be directed more toward dry seed production than to the other types.

(6) Flatulence is considered to be a major problem limiting the consumption of food legumes, and testing and screening methods should be developed to produce cultivars that do not cause this. Some people have a greater tendency toward the problem than do others.

Breeding for Nutritional Improvement

(1) Breeding for higher protein content should receive some attention, providing that protein quality or seed yield are not affected.

(2) Attributes contributing to cooking quality vary with different crops. There is a need to determine the importance of these attributes in relation to cooking quality, together with the development of rapid determination techniques.

(3) Genotype × environment interactions controlling cooking and nutritive quality are important and require further study. Preliminary data suggest a generally greater effect from environmental rather than genotypic factors, and different components of the environment (i.e., soil structure, fertility and fertilizers, trace elements, climate, and crop management) should be surveyed and studied against this aspect. Large-scale screening of seed material for cooking and nutritive qualities under detrimental environmental conditions may reveal genetic differences and enable selection and breeding for superior genotypes.

Food Legume Production

(1) The lack of basic information on improved production practices and availability of high-yielding varieties with resistance to adverse conditions, together with the poor

transfer of existing improved technologies, are recognized as some of the major constraints to increased legume production in most parts of the region. Identification of the major production constraints should be undertaken by an interdisciplinary group of scientists, including socioeconomic expertise, through the establishment of direct contact with the farmers concerned.

(2) The relative proportion of small- to large-scale farming enterprises should be assessed in any given situation, so that the research priorities can be modified to develop technologies relevant to that situation.

(3) The development of varieties and production practices permitting the mechanical harvesting of lentils should be considered as a priority.

(4) The demonstration of the economic viability of improved production technologies, and the provision of credit and inputs are essential to the effective promotion of new technologies in areas where such technologies are available.

(5) International support should also be given to research on other food legume crops such as dry peas, dry beans, and soybeans.

Diseases of Food Legumes

(1) Although it is recognized that different diseases require different methods of scoring, some standardization is highly desirable. In line with the need for computerization of data and for a simple practical approach to scoring, the following system should be used:

0	No data
1	No infection
2	Very mild infection
3	Moderate infection
4	High infection
5	Very high infection
6	Escape

This method of scoring is not intended for detailed pathological studies but rather for plant breeders making a general evaluation of hundreds or thousands of lines.

(2) International disease-screening nurseries are of great value and all national and international research efforts should be encouraged to exchange material and information in this and other ways.

(3) Based on the reported importance of the various diseases in the region, the following are considered to be research priorities: chick-peas — *Ascochyta* blight, root rot/wilt; Lentils — root rot/wilt; broad beans — chocolate spot, *Ascochyta* blight, root rot/wilt.

(4) Root rot/wilt diseases require further investigation to establish the major causal organisms in the various parts of the region. Centralized facilities should be established for the identification of root rot/wilt pathogens so that the presently confused situation can be clarified, especially in those countries that do not have their own facilities.

(5) Diseases of lesser importance should not be overlooked.

(6) Handbooks for the recognition, scoring, and control of the various diseases are urgently needed.

Pests and Pollinating Insects

(1) Priority should be given to the study of the biology, extent of damage, and control of the following insects: broad beans — aphids and bruchids; chick-peas — pod borers and leaf miners; lentils — aphids and bruchids.

(2) Other insects of secondary or localized importance that should receive research attention include *Sitona* weevil, thrips, and stem borer, the latter specifically on broad bean crops. The importance of the larvae of *Sitona* sp. in causing damage to root nodules needs assessment.

(3) Reports concerning the biologies of these important insects and the extent of the

damage caused by them in the various countries of the region should be compiled by ICARDA.

(4) A survey of pollinating insects in the region is also required.

(5) There is an urgent need for a comprehensive handbook covering the main insect pests of food legumes.

Weed Control

(1) ICARDA should extend its weed research activities to the region by supplying national programs with results of weed control trials and by collecting and disseminating information on the major weed problems, levels of crop losses, and current control methods in the various countries of the region.

(2) Cooperation in weed research is essential. There is a need to establish a series of cooperative weed control trials within the countries of the region, coordinated by ICARDA, who should supply the packages of materials and instructions for experimentation and analyze and disseminate the results.

(3) There is a serious lack of information on *Orobanche* and its impact on food legume production. National programs should be encouraged and assisted in their efforts to assess the extent of *Orobanche* problems in their countries and to develop and implement methods for its prevention and control, especially in the field of breeding resistant varieties.

Germ Plasm and Breeding Strategy

(1) There are obvious gaps in the collection of food legume germ plasm in the region and additional support is needed by the national programs for collection activities. ICARDA, in conjunction with the IBPGR and other agencies, should give assistance in fully exploring the region before valuable material is completely lost.

(2) A complete catalogue of all collections maintained at both the national institutions of the region and other relevant organizations, such as ICARDA, should be prepared and distributed to all the interested researchers in the region.

(3) With regard to agroclimatic conditions, altitudes, and latitudes, the Near East and North Africa can be tentatively divided into three subregions:

High Plateau Areas:	Iran and Turkey
Lowland Areas:	Syria, Lebanon, Jordan, Tunisia, Algeria, Libya, and Morocco
Southern Areas:	Sudan, Egypt, South Iraq, South Iran

(4) In order to better clarify the tentative divisions outlined above, a small-scale international trial comprising one or two of the best entries from each crop in each country should be conducted for 2 or 3 years. Scientists from the countries of the region should furnish seed of broad bean, lentil, and chick-pea to ICARDA as soon as possible to enable this program to be initiated.

(5) International uniform yield trials, screening nurseries, and segregating populations are of great importance to the research programs of the countries of the region and ICARDA should give considerable emphasis to this aspect of its work.

Agronomy, Physiology, and Microbiology

(1) There is a need for more detailed information on current production practices in the region, such as dates and rates of seeding, rates of fertilization, and weed control practices. A survey of the prevailing practices used by farmers would provide this information and should be seen as a priority.

(2) Intercropping of food legumes in perennial plantations is a common practice and its significance needs careful study.

(3) In view of the current variable results of N fertilization, investigations on crop response to starter dressings should be initiated.

(4) Studies of production under irrigated conditions should be expanded.

(5) Problems requiring priority research include: drought tolerance; photosynthetic efficiency; symbiotic nitrogen fixation; flower drop.

(6) Support is required from ICARDA and other agencies in the development of facilities for the production of *Rhizobium* inoculum.

(7) Coordinated agronomic research should be initiated within the region and details of the requisite trials and nurseries should be evolved by a working party comprised of researchers from national programs and from ICARDA.

Training and Communications

(1) Training in food legume improvement is required at three levels: technical training; training of junior scientists; training and meetings of senior scientific personnel. Courses in basic technical training, lasting for approximately 6 months and held at the ICARDA research station at Aleppo, are very useful, but short intensive courses in specialized subjects are also required by some national programs and should be organized by ICARDA if possible.

(2) A workshop/seminar on lentils should be held at Aleppo in 1979. There is a continuing need for general-type workshop activities to evaluate changes in national problems and research to reorientate ICARDA's approach to these changes. Such a workshop on grain legumes should be held every 3–4 years.

(3) Future workshops may be held either by ICARDA or by national programs, and in either case the participation of other national programs in the organization of such workshops would be highly desirable. These workshops should be more specific in their objectives and country reports should be more problem orientated.

(4) All available training material on food legumes should be gathered and compiled into comprehensive manuals for widespread use. Solid links should be forged between the training program of ICARDA and other pertinent training activities, such as are conducted by ICRISAT & FAO.

(5) ICARDA should undertake the compilation of annotated bibliographies on lentils, broad beans, and *Pisum* species, which could form a valuable source of information for researchers in the region. In addition, the publication of a regular general bulletin, containing news about food legumes and people working in that field, together with extension information, would prove very useful.

(6) In the light of the severe shortage of trained manpower specialized in food legume improvement within the region as a whole, international and national grant-giving bodies should actively support both graduate and technical training in this field, either directly to the trainees themselves or indirectly through the financial support of ICARDA.

(7) ICARDA should provide facilities, in cooperation with universities in the region, to support students undertaking research for higher degrees on subjects of relevance to the objectives of its food legume improvement program.

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